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## Discussion on the Individual Operation of Machine Tools by Electric Motors.

*Before the Franklin Institute, February 17, 1904.*

OPENING REMARKS BY CHARLES DAY.

I will not attempt to treat fully the subject under consideration, namely, the "Individual Operation of Machine Tools by Electric Motors," but rather present the matter in a way to facilitate discussion by those present.

The first application of the motor in workshops was probably in 1883, or only twenty years ago. It was estimated in January, 1903, that in the United States alone the motors operating in manufacturing establishments would aggregate at least 350,000 horse-power, and this figure has grown so rapidly since that time that any estimate I might make would probably be wide of the mark. These figures, however, will clearly indicate the recent development and tremendous growth in this field, and it would seem well, after three years, to again bring the subject before this body for discussion.

A paper on the "Motor Drive," by Mr. Daniel Adamson, presented March 14, 1896, before the Manchester Association of Engineers, one on "Electricity *versus* Shafting in the Machine-Shop," by Charles H. Benjamin, read at the Hartford meeting of the A. S. M. E., in May, 1897, and the discussion held here in January, 1901, all arrived at the same general conclusions, and only differ in the descriptions of types of apparatus.

A paragraph from Professor Benjamin's paper, written nearly seven years ago, is most interesting, as one constantly reads the same conclusions in the technical papers of to-day:

"The writer, as a mechanical and not an electrical engineer, hesitates to say much on this delicate subject. However, it is a question which must be settled at the outset in deciding upon the arrangement of a shop.

"The great advantages of the polyphase or induction motors are in their simplicity, their freedom from rubbing contacts and the constancy of their speed; the great disadvantage, the fact that the speed cannot be regulated.

"When electricity is to be applied simply to run line-shafting and counters, and the speed of separate machines is to be controlled by the usual belts and gears, the polyphase system is entirely satisfactory. On the other hand, when it is necessary to use independent and direct-connected motors on cranes and on machine tools, prompt and economical speed control is an absolute necessity; and it is here that the continuous-current machine has a great advantage. Without any prejudice, it is the earnest belief of the writer that the greatest advantage in electrical transmission is to come from the use of independent motors to the largest extent possible, and that the time will come when nearly every machine in the shop will have its own motor. Progress in this direction is slow, and the intermediate steps must be taken first; but when an electrician sneers at the use of direct-connected motors, one cannot but suspect that it is only because he has not yet perfected a motor that will satisfy the requirements."

When this was written motors were rarely directly connected to machines, and most machine-tool builders con-

demned the practice, while to-day several of the largest manufacturers of engine lathes have informed us that 30 per cent. of their product is designed for their use.

It is not surprising that the electrical engineer, who is familiar with the great improvements made in this apparatus, should clearly see the desirability of the motor drive; but to shop managers, not familiar with recent progress, the savings to accrue after the expenditures necessitated, are not assured. The man who analyzes the problem from the standpoint of earnings to be effected, and is not willing to spend money unless reasonably sure of an adequate return, finds nothing satisfactory in such statements as better crane service, ease of handling, proper location of machines, etc.

A number of papers have been written, however, since the last discussion here that throw light on the subject from other sides, and such work will surely do much to hasten the more general adoption of the individual drive. I refer to the detailed analysis of the problem from the standpoint of machine-shop requirements rather than the constant repetition of generalities, which mean nothing unless the means are available to make possible their fulfilment.

Such factors as independent location of machines and better facilities for handling work are interesting, but are they worth while? In other words, is the constant-speed individual motor drive a paying investment? Ease of handling and speed control are terms that one constantly hears; but is the additional expenditure necessary to obtain them justified from a consideration of dollars and cents? Some concerns have gone ahead blindly, simply accepting the statement that the individual drive is the proper thing, and in almost every instance the resulting equipments do not begin to possess the possibilities that they should, and in many cases are not yielding a return to justify the expenditure.

Until it is fully understood that the words "a motor-driven tool" need not necessarily imply high efficiency, the advantages made possible by the use of the best types of such apparatus will not be gained. I feel that I cannot dwell too long or forcibly on this point. The tool steel, the

machine, the motor, the man, are all but means to an end. Let us always first bear in mind this end. Machinery designed to fulfil the conditions of economical production is the machinery that will be purchased, not only once, but repeatedly, and that is what is needed to perpetuate this work. We can all point to large motor-driven equipments —usually the first installed; will they be duplicated or extended? Only if it can be clearly shown that a proper return has resulted. As stated above, a number of the largest equipments do not possess the possibilities anticipated; in others they may be present but of no earning value, on account of lack of intelligent direction of work. This is equally true of belt-driven machines; but the motor drive, with its greater possibilities, should only be adopted as the result of a definite need.

The shop manager who does not see clearly the inability of a belted tool to attain maximum output, and the reasons, cannot hope to gain appreciably by purchasing a motor. Let me repeat, a motor-driven shop does not insure low cost of production any more than efficient guns can guarantee a naval victory.

The intelligent direction of work involves many more factors than most shop men realize, and hence we find success of the same degree, as far as earning power is concerned, resulting from innumerable causes. The plant with the most modern equipment may not profit by it to an appreciable extent, but nevertheless pay large dividends because the selling organization is under the direction of one possessing an exceptionally keen insight into the motives of prospective purchasers.

I may seem to digress from the subject at issue, but I want this meeting to stand apart from all others in that the motor drive be considered from the standpoint of a money earner. The time has arrived when it would be much better to close one's eyes and grasp any one of possibly four makes of apparatus, devoting the time to its proper installation and operation, rather than reversing the process, as is so often done.

The manufacturer of electrical apparatus for machine-tool

driving, who is desirous of obtaining the greatest success, must not only make efficient motors and controllers, but see that they are *properly installed and their use understood.* An electric generator or steam engine may be heavily overloaded and break down, but this may be no discredit nor harmful to the reputation of the maker, for it is usually an easy matter to locate the trouble. The *earning power* of such an installation is largely dependent upon the design and workmanship—features that can be passed upon before the machinery leaves the works. If the power plant is found to be too small, more units can be readily added without in any way interfering with those in use. Consequently, these two classes of work present distinctly different problems to the engineer.

In many instances the individual drive is justified by greater facility in handling material, made possible by operating cranes over the tools. This return is dependent only upon the absence of overhead work, and is not affected by size or type of motor. The great advantages claimed for the direct-current, variable-speed motor, however, are based upon the saving effected on the operator's time which, in turn, depends upon his ability to run his machine at all times to its full capacity, or rather machine each piece of work as rapidly as its character will permit.

Concerns that market motors to fulfil certain conditions on the armature shaft, requiring the customers to decide whether these conditions are right or wrong for their needs, are sure, as time goes on, to find many of them dissatisfied. The electrical companies pride themselves upon the efficiency of their apparatus, but frequently the purchasers, through improper selection of sizes and types, are anything but pleased, being unable to reap the return that they understood was sure to accompany a motor-driven equipment.

It is claimed, and rightly, too, that the enormous amount of detail work required to do justice to the engineering features, in connection with the adaptation of motors to machine tools, cannot be handled without an additional charge. To do this work superficially is in many cases more harmful than not to do it at all.

I do not intend to take up your time now with details, but will say that after equipping over 100 machines of different types and sizes, we are prepared to speak with confidence as to the cost of such work. To make the necessary study of requirements, and work up complete shop drawings for all parts needed, averages in flat cost $150 per machine. Unless handled in this way the shop cost is sure to be excessively high.

If the average shop manager had the information at his disposal, and the time and facilities to enable him to properly equip such old machines as would justify it and intelligently purchase new ones, the problem would be a comparatively simple one. This is true in some establishments—machine-tool builders for example; but we cannot expect those in charge of large repair shops for railroads, collieries and other industries to have either the time or experience to conduct this work properly. Considering the rapid development in this field, much work already completed has been handled as creditably as could be expected; but, at the present time, nearly all the principal electrical companies are giving much thought to this subject that they may meet the requirements of their customers to the best advantage.

Progress is clearly shown in the accompanying illustrations. *Fig. 1*, illustrates a New Haven engine lathe equipped about twelve years ago in accord with drawings furnished by the Crocker-Wheeler Company, which purchased it for their own use. Some explanation will be needed, as the lathe has been modified, if I remember correctly, from the original design. The arms shown on the front of the headstock originally operated rheostats, a certain amount of speed control being obtained by armature resistance. This method being found unsatisfactory, the motor was run at constant speed, the necessary spindle speeds being obtained by the nest of gears which fill the space originally provided for the resistance coils. This equipment, notwithstanding its crude character, made it possible to operate a crane over the machine and, if the motor had been large enough, would have possessed practically all the advantages of the present induction-motor system.

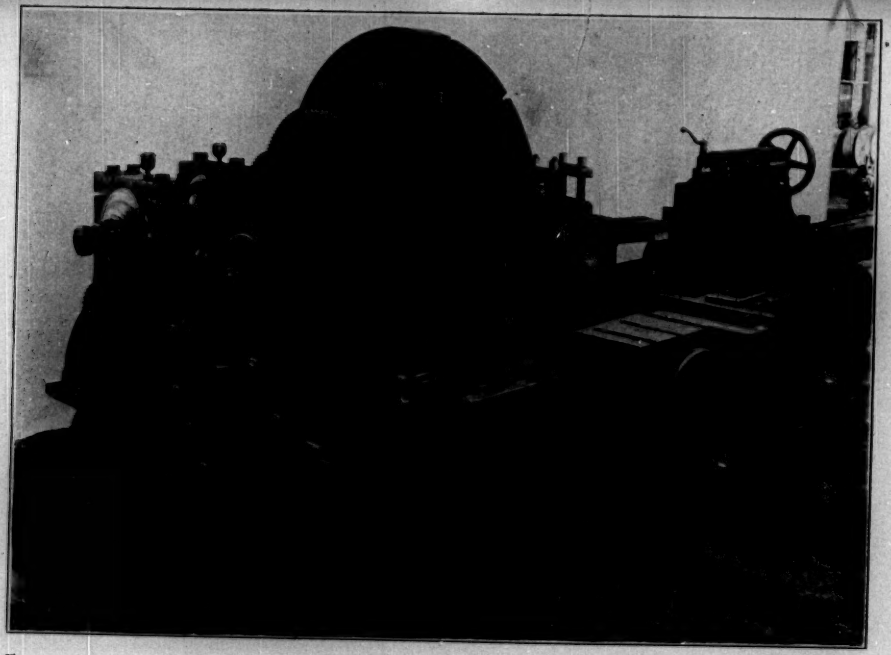


FIG. 1.—One of the first motor-driven engine lathes equipped by the Crocker-Wheeler Company for their own use.

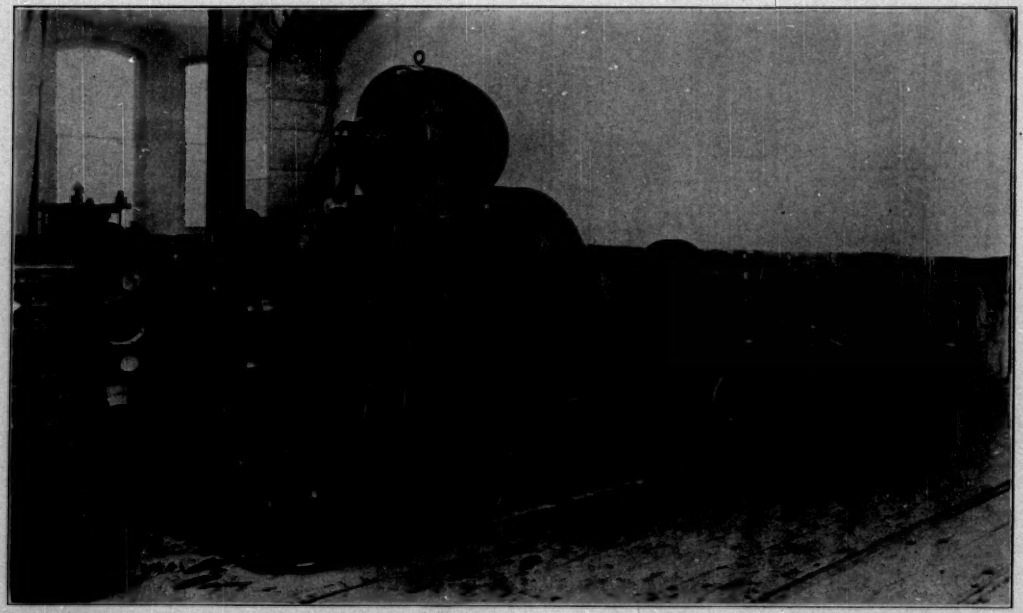


FIG. 2.—50-inch Pittsburg lathe, arranged for motor driving by Dodge & Day (Crocker-Wheeler multi-voltage apparatus).

Compare with it *Fig. 2*—a 50-inch Pittsburg lathe designed for belt drive, but now equipped with apparatus also manufactured by the Crocker-Wheeler Company. We have engineered the equipment of a number of large engine lathes which might appeal to the eye much more than this one as being more symmetrical, etc. I chose it, however, on account of its rugged character and the increased output made possible by the change. Practically all the original driving gears were replaced by new ones of greater strength, and the ratios changed so that with the range in motor speeds obtainable a uniform increase in speeds would result. It is not necessary to dwell upon the good features of this equipment, as most of you are familiar with them. The ease of handling secured by the operation of the controller from the apron, where at all times the operator has the machine under perfect control, adequate power for any work that the machine is adapted for, simplicity of the entire arrangement, so that a workman of ordinary intelligence can grasp, in a few moments, the method of operation, are the points which suggest themselves at once. Unfortunately, we have no statistics showing to what an extent the possibilities of this tool have been increased, but experience would indicate that, under average working conditions, metal could be removed at least twice as fast as was originally possible. We prefer to be rather conservative in making such estimates, but I can speak with confidence on this point, as the matter has recently been strikingly brought to my notice in the shops of one of our clients where we have similar machines running side by side, one being operated by belt and the other by motor. The belt-driven machine has every advantage which we could give it. A special countershaft was designed with tight and loose pulley in place of the ordinary friction clutch; the belts all kept at a proper tension and so designed that the cone belt would be the first one to fail. The ordinary method of lubricating the spindle, which so often gives trouble when doing high-speed work, was replaced by a special arrangement which we have found very satisfactory. The motor-driven tool was equipped with a Bullock multiple-voltage motor, the

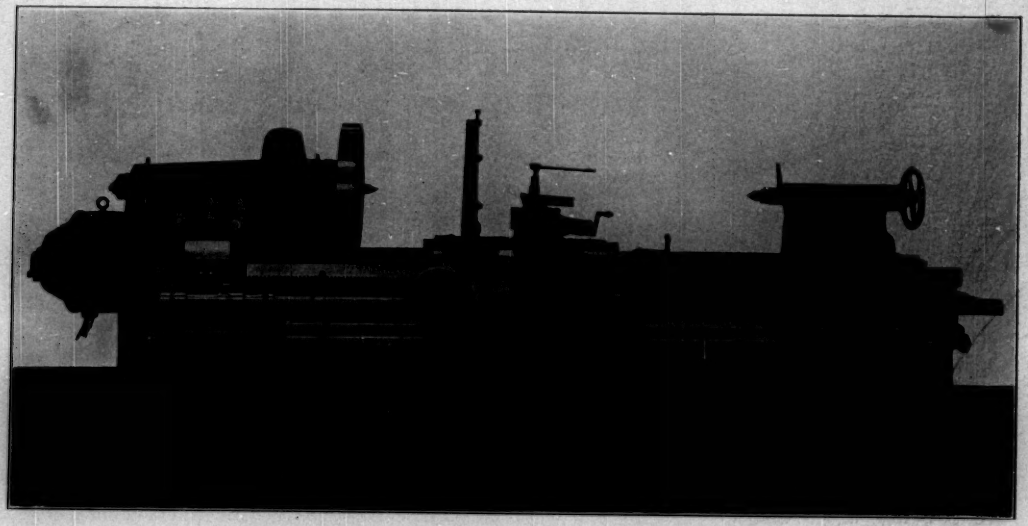


FIG. 3.—New model Pond lathe equipped with Westinghouse type S motor.

general character of the equipment being similar to the one just illustrated. The job in hand at the time referred to consisted in the roughing of shaft journals, the conditions arrived at on the motor-driven machine representing the full capacity of the cutting tool. On the belt driven tool it was not possible to use more than one-half the feed, and even then the belt slipped badly. It is, of course, a comparatively simple matter to figure this problem out. Those in close touch with machine-tool design know that in the average machine power is usually sacrificed to obtain a sufficient number of speeds on the step cone, but to see the two machines side by side, working under the most favorable conditions on the same work, tells the story more clearly and forcibly than is possible in any other way. Of course the best results will only be reached when machine tools are *primarily designed* to take advantage of every known means toward the attainment of economical production. Such an equipment is illustrated in *Fig. 3*, being a Pond lathe equipped with a Westinghouse type S motor.

Actual figures showing earnings effected are what are needed to-day, and such information as the comparative costs of individual and group drives in the Collingwood Shops of the Lake Shore & Michigan Southern Railroad is of great value. The conclusion is reached that if the machine-tool builders can market machines suited for motor driving at the same price as the belt-driven type, it is as cheap to equip all large machines with individual motors as to drive them from line shafting. It has also been shown that the average yearly expense of operating these tools with variable-speed motors is $1,725.70, while it would be $1,687.10 if the constant-speed type were adopted. These figures are based on a liberal rate of interest and depreciation, and those who wish to refer to them can find all the data in the report of June, 1903, of the Committee on Electrically Driven Shops, appointed by the American Railway Master Mechanics' Association. The committee state that as the difference in operating cost between variable-speed and constant-speed motors is but 2¼ per cent., it is only necessary to obtain an increased output of this amount to

justify using the variable-speed type. This conclusion does not hold in actual practice. The substitution of the variable-speed for the constant-speed motor does not bring in 2¼ per cent. more work, nor does it make it possible to dispose of any equipment, so the saving of $38.60 must be made on the labor item only. As the latter was $840, an increase in output of at least 4½ per cent. should result. If, on the other hand, the proportion of the man's time had been a smaller item, a proportionately greater reduction in time would have been necessary. It is not my desire, however, to criticise this data, for I feel that it is just such investigations that are most needed at the present time. This analysis shows the economy that must be effected to justify the use of the variable-speed motors, but no attempt was made to analyze the problem from the other side; namely, to see what saving actually should occur after the installation of the apparatus.

Mr. R. W. Stovel, when working on the equipment for the Pittsburg & Lake Erie Railroad, obtained some interesting data in this connection, his conclusions being as follows:

"It is to the advantage of any machine shop to put an individual motor on a 16-inch lathe, provided this tool is busy throughout the shop year; that is, keeps one man busy all the time on a variety of work. It is advantageous to put an individual motor on all variable-speed tools which are busy throughout the shop year, regardless of their horse-power requirements. It is also to be deduced that since no credit has been allowed for shafting or motors allowed for group driving, it will actually pay to change existing shops to individual-motor drives."

Those who care to look into this matter further can probably obtain a copy of the paper which he presented before the Railway Club of Pittsburg. The paper was written some time ago, but his method of analysis is quite as interesting now. The problem is so complex that results obtained in one establishment are of little value in connection with another, and it is never possible intelligently to consider the advisability of installing motor drives unless

conversant with the general character of work to be performed and shop practice in vogue.

That there is still a great difference of opinion on this subject is amply proven by the letters published a short time ago in the *Railroad Gazette*, and such differences will continue to exist until more accurate data, relative to machining and means of attaining full efficiency under imposed labor conditions, are available. The simple relations between cutting speed, feed and depth of cut for different material are known to but few, and upon this data depends the proper selection of apparatus.

I do not intend to discuss the various types of apparatus, and will only say that no radical departures have been made in principle of operation since 1901, when Mr. Gano S. Dunn described in this room the various means that were then resorted to for obtaining variable speed. The multiple-voltage systems using field weakening for intermediate speeds have been quite generally adopted during the intervening period, the apparatus having been greatly perfected, as stated above. Let me again repeat that everything depends upon the proper selection of motors and controllers, followed by intelligent installation and *operation*.

Many details I have not touched upon will, I hope, be covered in the discussion. I will close my remarks, which have already taken up more time than I intended, with a slide (*Fig. 4*), showing the interior of the new machine-shop of the Jeanesville Iron Works Company, which is characteristic of the modern shop of to-day. The Pittsburg lathe, shown on the previous slide, will be seen in the foreground; just beyond it, a 60-inch Pond lathe; and on the left, a Gray planer and Betts boring mill. The splendid facilities for handling material, the natural lighting and numerous other features mark the difference between this shop and those erected some years ago.

I stated in the beginning I would not be able to even allude to many matters of great interest, such as the radical changes in design that machine tools are undergoing as a result of improvements in tool steel and the adoption of the motor drive. In this connection I will only say that the

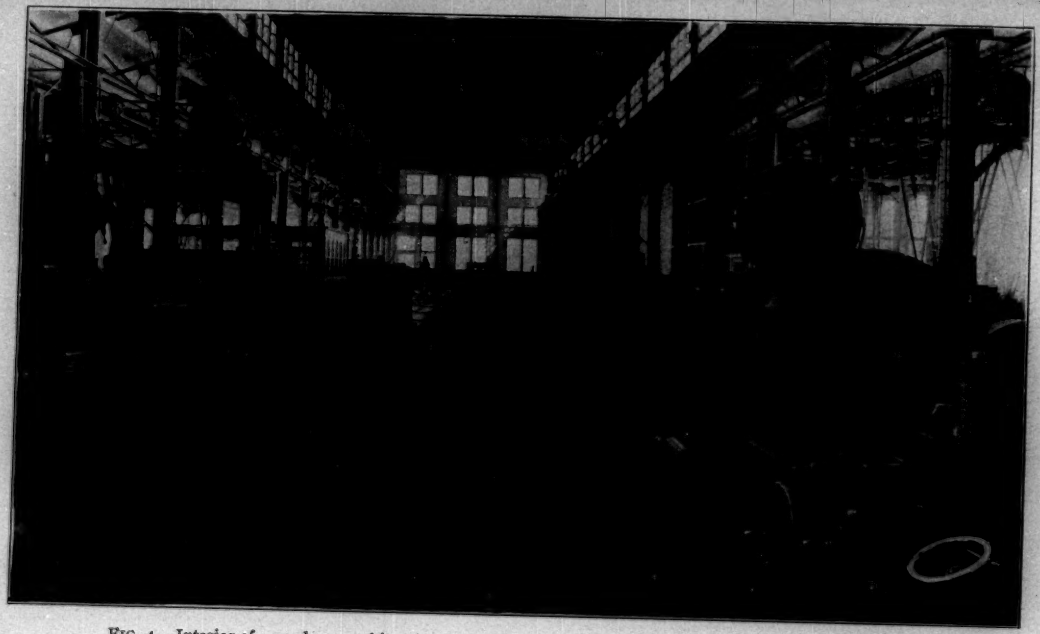


FIG. 4.—Interior of a modern machine-shop, showing location of motor-driven tools under traveling crane.
(Jeanesville Iron Works Company, Hazleton, Pa.)

next ten years are likely to bring changes so radical in character that we can hardly realize them now.

DISCUSSION.

MR. GANO S. DUNN:—The present meeting recalls clearly the discussion on this subject before the Franklin Institute, in November, 1900, and a comparison of the views just expressed by Mr. Day with the conclusions of four years ago enables one to realize fully the substantial progress that has been made. At that time engineers differed widely upon many details that have since been definitely settled, and, in general, there is no longer any doubt as to the advantages of the electrical distribution of power in industrial plants.

The more general appreciation of the individual drive through a better understanding of shop requirements, and the realization on the part of the machine builders and electrical companies of the need for thorough co-operation, is rapidly placing this work on a firm footing that is in marked contrast to its position a few years ago.

A perfectly frank and intelligent treatment of each individual case is necessary, and one equipment yielding a proper return is a better advertisement than a dozen "show plants." Those who do not comprehend fully the situation, through lack of experience in industrial work, frequently attach a certain amount of mystery to the motor drive, but manufacturers who count on a certain return from every dollar invested for betterment or extension are not greatly interested in advantages so subtle that they cannot be defined.

An engineering department competent in not only the electrical details of manufacturing plants, but in the mechanical and executive features also, with sub-departments to specialize on different industries, is not only of inestimable value to the electrical companies in establishing a basis for intelligent design, but insures for their customers *the results* that they are primarily after.

In the four years that have elapsed since the last meeting on this subject, no radical changes have resulted in the various systems used for obtaining variable speed, although

certain of these systems have become well established and quite generally adopted by large manufacturing companies. Where a given shop is to be equipped with motor drive, and the one object is to attain the highest general efficiency of the plant, those in charge of the work can have the greatest latitude in their decision. The multiple-voltage system, in such instances, possesses marked advantages that, at the present time at least, are not true of other systems. Motors operating on this system give even less trouble through commutation or heating than the same motors running at constant speed, which is not true of any of the systems where a wide speed range is obtained by field weakening only.

All the considerations referred to at some length by Mr. Day should be carefully borne in mind by customers purchasing for their own use. The machine builders, on the other hand, are restricted by certain commercial factors which prevent the selection of apparatus that cannot be operated in the ordinary plant where their product is solicited. To meet their requirements, we are called upon to exert our best efforts toward the development of single-voltage, variable-speed motors. Modern manufacturing methods call for machine tools designed for special duty, and this class require a comparatively small range in speed.

It is true that machine-tool duty, through its intermittent character, will permit of a special basis of rating; but, until some standard is adopted, the customer is likely to be misled, unless he clearly defines the overloads required and confirms them by actual test.

The advantages possessed by the individual drive ultimately depend on the reliability of the apparatus—a factor too often overlooked; and the desirable system is one that not only fulfils requirements, but, at the same time, assures a minimum of interruption through controller or motor troubles.

Controllers for machine-tool duty have undergone a marked evolution during the past few months, the latest types made by the company with which I am associated being so rugged and generous in all details of construction

that faults heretofore inherent in such apparatus have been wholly eliminated.

There are numerous details of this subject that no doubt could be discussed for an entire evening, but it is the consensus of opinion concerning the general problem that is sought now.

Not very long ago many hesitated to assert definitely that the motor drive had come to stay, while to-day it is only a question of what kind of motor drive. I feel perfectly confident that the individual drive will soon be adopted for even very small machines, and, indeed, Mr. Day's figures concerning the output of a number of the leading machine builders can leave little doubt in our minds as to the growing popularity of individual driving.

MR. F. B. DUNCAN:—In discussing Mr. Day's paper it is well to take cognizance of the two great factors involved —the financial and the human

(1) Does it pay?

(2) How can we convince people that it does pay?

The first question has been well threshed out, and while many foolish investments have been made in motor equipment (as foolish investments have ever been and will continue to be), yet, on the whole, electrically operated machine tools have paid well.

Better placement of tools, especially the larger ones. The operation of powerful portable apparatus for use on the very largest work. Better crane service due to the absence of belts. The inestimable boon of the electric crane itself. Better light. Less dirt. Less danger to employees. Lighter overhead construction necessary in new factories due to non-existence of countershaft, etc. Fuel economy in many (but not all) instances; and last, and greatest of all, abundance of power to pull a cut of the most generous proportions at the highest speed permissible with the new high-speed tool steels.

The above reasons all are convincing that motor-driven tools pay, but chiefly the latter; for, as our foreign friends would say, "It is to laugh" to watch one of the standard belt-driven tools endeavor to cope with an ambitious ma-

chinist in combination with a well-made tool of the new high-speed breed.

Properly presented and explained to a manager or superintendent of ordinary intelligence, electrical equipment of machine tools is self-convincing, and this brings us to the second question:

How can we convince people that it does pay?

It is very fortunate that the new tool steels had arrived on the scene just when they did, as they necessitated the complete re-design of the existing machine tools, and if the electrical fraternity do their duty the new tool designs made necessary will be arranged with electrical operation as the *primary* and belt drive as a *secondary* consideration.

No permanent advance in electrical operation of machine tools will be made until the motor and the tool are designed for each other as much as the old cone pulley was designed for the machine on which it was used.

An electro-mechanical tool concern, or rather a multitude of them, is the crying need of the hour. Electrical-machinery builders and machine-tool builders have each wrestled with the problem separately and with each other collectively, and the result has been some progress, and once in a thousand times a fairly passable design has been worked out; but, on the whole, a most atrocious lot of abortions have been foisted on the long-suffering public.

It is not the fault of the designs of either part of the equipment. The motor makers made good motors and the tool men made good tools for their purpose (before the new steels made them ridiculous); but the trouble has been and is that the problem has not been attacked in the right way and very little progress (comparatively speaking) has been made in the past ten years in regard to perfecting the electrical operation of metal-working tools. The *quantity* has increased enormously; the *quality* has remained about stationary.

In a shop exclusively electrically operated with over 500 motors, this fact was forcibly brought to the writer's attention. Some motor-driven tools were installed over twelve years ago, and yet the same crudities of attachment

to the tool are being perpetrated on the recent tools as were on these installed in the dawn of motor drive.

The illustration (*Fig. 2*) shown by Mr. Day emphasizes this fact; for, although a good example of the best up-to-date practice, it is yet a disgrace to the art and an eyesore to any one who reflects for a moment on what might be accomplished by a progressive concern that would merge the tool and motor design into each other with the view of turning out the most efficient unit possible.

Some may ask what this has to do with convincing the managers of the metal-working industries that motor drive pays.

It has everything to do with it.

A progressive superintendent or manager partially acquainted with the possibilities of electric drive hears something about it (probably from an enthusiastic electrical salesman), decides to order a trial machine; when he gets the outfit, the appearance of which nearly always violates the ethics of correct design (and whose actions too often are unreliable, especially in regard to speed control), he is apt to become discouraged in his search after electrical knowledge.

What is needed (and this cannot be emphasized too strongly) *is a complete re-design of present machine tools with motor operation alone in view.*

The idea must also be abandoned that standard motors can be bought and "hitched up" to a tool originally designed for a belt drive, with the result of obtaining a satisfactory outfit.

It can only be done in a very few instances, and what is needed is an entire line of machine tools designed electrically and mechanically for the production of the *greatest* amount of work in the *shortest* possible time.

The tool builders and electrical men may well take a leaf from the experience of the automobile manufacturers. Until the latter abandoned standard motors, engines, bodies and gears, and evolved, appropriated and combined types made necessary by the exigencies of the case, no substantial progress was made; but since they have evolved new

which are more or less imperfect in design. If such a device is perfected, it will undoubtedly revolutionize machine-tool driving, as a constant-speed motor only will be required, and the alternating current (or induction motor) would supplant the direct-current motor now in use. However, all the commercial devices of this kind that I have seen are either very inefficient, too complicated or too bulky for the duty required of them, and it seems better to maintain the drive as a unit and obtain the variation electrically through a reasonable range.

In conclusion, I would again call your attention to the advisability of consulting a thoroughly competent engineer in laying out new machine shops, or in re-equipping old ones, for it is cheapest in the end.

MR. F. M. KIMBALL:—I agree quite heartily with the general conclusions set forth in Mr. Day's paper. The points I should emphasize particularly would be:

(1) That, in the selection of motors, the financial aspect of any proposed investment must be considered fully as much as the technical aspect. From the engineering standpoint alone, we would often advise a certain form of equipment which, when the necessary investment to procure it is considered and the cost of operation and maintenance is compared with increase in production gained, would be found unwise.

(2) In other classes of business, where, at first sight, an installation involving low capitalization might seem desirable, a further consideration of the value in the increased product and the decreased expense of this product, due to the elimination of manual labor or attendance, will fully justify us in spending the larger amount of money to begin with.

(3) There is no doubt that, as a general statement, the cheaper the electricity supply becomes, the lower the manufacturers are able to produce good motors; the higher the trades unions drive the price of labor and the larger the market becomes for any given item of product, the more advantageous will it become, from all standpoints, to adopt individual drive as against group drive.

(4) I am still of the opinion, advanced some two years ago, that, in general problems of machine equipment, speed variation by the motor of one to three on single voltage, and one to six on double voltage, is all that is necessary. The remaining requirements can better be met mechanically. The coarse changes in speed can nearly always be made by change gears or their equivalent, and the intermediate and finer gradations of speed can be effected electrically.

(5) While, from the theoretical standpoint, the individual equipment of every tool and the use of motors having extremely wide speed ranges may be desirable, yet commercial considerations, which cannot possibly be overlooked, will largely modify this conclusion when definite manufacturing problems are being worked out.

MR. R. T. LOZIER:—Mr. Day has quite fully stated why electric motors have been selected in a number of important machine-shops to drive certain of their tools, and we are all willing to grant that the output of such tools is increased by their use, and that that is a good reason for their adoption.

The French say, "A man is happy when he knows what he wants." This may be a shop superintendent as well as any other fellow. Now, therefore, the main question is just what does the shop superintendent want in the way of a motor equipment?

In an article that I have just completed on this subject for the *Electrical Magazine* of England, I suggested the following plan:

Divide the tools of any shop under two general classifications, viz.:

(1) Tools which warrant the investment for individual motors.

(*a*) Those in which it is desired to vary the speed and to have a source of power that will stand up to the work put upon it; so that as a resultant of these two factors the output of the tool is materially increased over that obtained by the belt drive with its limited speed ranges and inefficient power transmission.

(*b*) Those tools in which the convenience gained by the individual motors is sufficient to warrant that investment, viz., permitting of a clear space for the overhead cranes to work in, and, with improvement in light and ventilation, more economic shop arrangement; and particularly those tools that cannot be conveniently reached by line shafts and belts.

(2) Tools which do not warrant the investment for individual motors.

These tools are those that run at fixed speeds not often varied, and which occupy that part of the shop where group driving by line shafts does not interfere with the crane work.

Having made this first general classification, the next step would be to select the speed range for the variable speed tools and the method for obtaining it. This can be determined easily in the following manner:

The rotary machine tools may be said to represent the limits of speed variation, and the following general rule applying thereto can be stated as follows:

The minimum or lowest speed of the range that such tools will run at is determined by the hardest material to be machined when taking a cut at the largest diameter that the dimensions of the tool permits.

The maximum or highest speed of the range is determined by the softest material and the smallest diameter at which the tool will work efficiently.

Let us assume that a 26-inch lathe represents the maximum speed requirements of average work, and that it is to handle high-carbon steel at a cutting speed of 12½ feet per minute.

If the carbon machine has a circumference of 26 inches diameter, the spindle (or face plate) of the lathe will run at 1·8 revolutions per minute.

If this same lathe is to machine cast iron at 120 feet per minute cutting speed, and as small a diameter as 2 inches, then the spindle (or face plate) will run at say 225 revolutions per minute.

This gives a ratio of about 125 to 1.

Now, of course, no electrical system can ever give that

range; so we will take two back gears at 5 to 1 each, and a motor having a 5 to 1 ratio of speed variation also (5 times 5 times 5 = 125). With both gears in and the motor running at its lowest speed we get 1·8 revolutions per minute.

At this point we increase the speed of the motor by selected increments until we reach (1·8 times 5) 9 revolutions per minute.

The second gear is then dropped out, the motor put back to its slowest speed and without gear reduction we still have 9 revolutions per minute. We again speed up the motor and get (9 times 5) 45 revolutions per minute.

The first gear then drops out and the motor is brought down to its lowest speed, driving direct at 45 revolutions per minute, which speed is increased by the motor's control up to (45 times 5) 225 revolutions per minute.

For such tools as do not require such a broad range but one back gear is used or the motor drives directly on to the tool-shaft as the speeds may require.

It will be noted that all the intermediate changes are made by the motor, which can readily be varied in its speed while the tool is doing its work; so that this method provides the shop superintendent with a perfectly practical range of speed that will cover almost any class of work with as many steps in his motor-control as he may want, and which can be applied to any extent he may desire. The nature of the work may determine other ratios to be more desirable; that, of course, can be worked out in each case by the rule given above.

Now, having determined what tools are to have individual motors and, secondly, what their speed range should be, the next point will be to determine how much power each tool will require and the kind of a motor to produce it. No general rule can be laid down, I believe. The nature of the cutting-tool, the method of transmitting the power to it through the machine's driving gear, and the losses involved in that transmission, vary in each case and their values can only be obtained from actual tests.

Modern machine-shop practice, as concerns cutting speeds and feeds, has made worthless the figures that were furnished for belt drives.

This work requires the services of an engineer who not only understands the mechanical requirements of the tool, but who will also be able to lay out a system in which all the requirements of the electric plant will receive their proper value.

MR. JAMES CHRISTIE:—Mr. Day's paper brings out very clearly the importance of carefully considering the nature of the work and the general conditions of practice which are to be encountered before deciding on the details of the electric-power equipment of a shop. Certain machines, from the nature of their operation, or the character of the work which they are to do, can be most advantageously operated in groups, from a countershaft driven by a constant-speed motor. Others require an individual constant-speed motor, as, for instance, where location is important, and crane service must not be interfered with; and still others require individual variable-speed drive.

Small lathes and other small machines do not require heavy crane service, nor is the difference in diameter of work sufficient to make speed control a necessity, so that with machines below a certain size, it is often best to drive in small groups from a constant-speed countershaft. With boring mills and large lathes, the variation in diameter of the work, and, consequently, the widely varying peripheral velocities and the necessity for having crane service, make individual variable-speed drive most desirable.

Individual constant-speed motor drives have been in use for many years in the Pencoyd bridge shop. This method of driving is generally very suitable for bridge-shop machines, owing to the large size of punches and shears, and the necessity of locating in exactly the proper position without interfering with the crane service. The functions of these machines are, at the same time, such as not to require variable speed.

We have recently installed a multi-voltage system in our new machine shop, and although it has not been in operation long enough for complete tests to be obtained that would be of value in comparison with belt-driven shops, we have had opportunity to draw certain general conclusions

as to its value. Variable speed is a distinct advantage in such cases as the facing of discs on lathe or boring mill; for, as the tool proceeds from circumference to center, a comparatively uniform cutting speed can be maintained without interrupting the operation, simply by altering the speed of the motor.

The effect of having a wide range of speed under easy control is an encouragement to the workmen to experiment with cutting speeds, and they quickly learn the maximum speed which material and tool steel will allow. A great deal of the trouble incident to the use of a multi-voltage system arises with the controllers. Most of it is confined to the controllers on the smaller machines; the small nature of the work requiring far more frequent stopping and starting, with the consequent wear and tear, than on the larger machines. The system provides for six voltages, ranging from 40 to 240 volts, and intermediate speeds can be obtained by throwing in the back gears or weakening the motor field.

Field regulation has not proved entirely satisfactory in some cases, sparking and momentary variations in the motor speed being the consequence. On this account, it was found desirable in some cases to cut out points on the controller that threw in the field resistance, and to rely only on difference of voltage and the back gears for speed changes. It is best that reduction in speed be obtained whenever possible by the use of the back gears, rather than by using a lower voltage, not only because a higher efficiency is insured, but also to avoid having too large a proportion of the shop power drawn from the low voltages, with consequent overloading.

The increased cost of installing a multi-voltage system over that of a constant-speed system is considerable; the difference arising not only from the more complicated nature of the wiring, starting devices, etc., but also largely from the fact that a motor for a multi-voltage system must be five or six times as large as the constant-speed motor to do the same work. The motors for a variable-speed system being larger and the starting devices, etc., more complicated

than in a constant-speed system, the cost of repair and maintenance is, of course, greater in porportion.

These various methods of motor drive are each best suited for certain conditions, and, if properly applied, will, undoubtedly, produce more satisfactory results and reduce the shop cost; but it is necessary that the bearing of every condition be carefully considered.

PROF. ELIHU THOMSON:—This is a specialty to which I can hardly claim to have given more than the most general attention. Our business has so many ramifications that it is impossible to follow each one of them in detail. There are men who have given careful and special study to the particular subject under consideration, and to these I would defer.

My general opinion is that there is no hard-and-fast rule which can be laid down, everything depending on the conditions of use of the machine tools. In some cases the group drive will undoubtedly hold its own, and perhaps in other instances the belt, counter and line shaft will be retained. The individual drive is likely to continue to replace the older forms, particularly for the larger tools, and for those kept in active service at maximum output. The accumulation of data on the subject is gradually becoming such that it will be possible before long for competent engineers to determine the desirability or undesirability of resorting to individual operation by motors.

A modern works of any extent now requires its engine-dynamo in power-house to be conveniently located, with connecting lines from which power is obtained from electric motors, sometimes to drive line shafting, serving groups of machines more or less extended, and at other times driving certain machines individually.

The case of each factory or workshop is, it seems to me, one which needs to be considered by itself, with a careful estimation of all that goes to increase the economy of the operation.

MR. W. COOPER:—The subject, "Use of Electric Motors in the Machine Shop," is one to which I have given considerable thought, and have assisted in making a great many

different applications. The conditions of operation of the machinery of a machine shop are not ideal for an electric motor. In the first place, the work done by nearly all machine-shop tools is very intermittent and variable in character. Ordinarily the work being done calls for a very small amount of power, while at times the demand is very great. This is especially true in the individual application of motors to the machines. It is, therefore, necessary to equip any given machine with a motor which will have sufficient capacity to do the maximum amount of work. Such a motor will necessarily be operated a greater portion of the time at a very small percentage of its capacity, and consequently comparatively inefficiently. This very condition has led to the use of motors that were entirely too small for the maximum work that they will be called upon to do, the assumption being that they would be large enough for the average work, and could probably stand the strain for short periods of the maximum demand.

Another reason why the use of motors in machine shops is not more general and is not increasing more rapidly is that the applications made bristle with errors.

In many instances the motor has been out of all proportion to the work to be performed; in a great many cases unnecessarily powerful, and in a great many cases too small. In the former case, of course, the motor does its work without distress, while in the latter case, in a good many instances at least, absolute failure has been the result. In the individual application of the so-called variable speed motors, the motor is usually overworked at some point in its range. The fact is that if a very wide range of speeds is demanded from the motor, its size increases very rapidly with the increased range, and soon becomes inordinately large for the smaller class of machines. If a very wide range in the motor is employed, the electrical equipment often costs more than the machines to which it is applied. While this does not necessarily signify an uneconomical arrangement, as the advantages derived may many times offset the increased investment, still the increased first cost is a factor to be dealt with. During the last two

years the individual application of motors to machine-shop tools has been thrown into a very unsettled condition, so much so that it is difficult to determine at the present time all the features governing the case. During this period the high-speed steel has come into quite general use. At the same time the underlying principles involved in the use of motors for machine-shop tools has become better understood. During the first experiments in the use of the multiple-voltage system for getting variable speeds, the motor got decidedly the worst of the bargain. There seemed to be some idea that on the lower voltages and at the slower speed the motor could keep up its end on account of its running at such a slow speed that there was no tendency for the motor to spark. It was soon found, however, that there was something wrong in the arrangement, and that the motors would not have the pulling power at the slow speeds, and also that the inherent regulation on the low voltages was very poor. Also in the earlier uses of the multiple-voltage system no attempt was made to graduate the speed by field regulation, the entire speed range being covered by varying the voltage. This had the disadvantage of requiring either a very low voltage for the slow speed, or a high voltage for the highest speed, and to build a motor that would operate satisfactorily at the two extremes and still be moderate in size, seemed to be a very difficult task, which indeed it was. Another point that was decidedly wrong in the first uses of the multiple voltage for variable speeds was that variation between the voltages was made a constant, bringing the voltages in as near as possible arithmetical progression, while they should be in geometrical progression. This is certainly obvious, when the matter is given consideration and figured out carefully on the basis of increased cutting speeds or increased rotative speeds. When shunt-field regulation was applied in connection with the multiple-voltage system, it was found that a wider range could be covered satisfactorily, or the same range could be covered with a narrower range of variable voltages.

In a paper which I read before the second meeting of the

Cincinnati Chapter of the American Institute of Electrical Engineers, February, 1903, and published in the *Transactions* of the American Institute of Electrical Engineers for April, 1903, some of the fundamental principles underlying the use of a shunt-wound direct-current motor for variable speeds are pointed out. In that paper is shown that where formerly the four-wire circuit for a multiple-voltage system with a ratio between the extreme voltages of about six to one had been used, the same results could be accomplished by using a range of voltages of about two and one-half to one and a three-wire system. The following rules were deduced as conclusions from that paper:

(1) The total range of speed, using both variable voltage and field regulation, will be as the square of the range of voltages.

(2) The change of horse-power will be directly proportional to change of voltage on armature, field being constant.

(3) The change of horse-power by change of field strength will be inversely proportional to change in speed, the voltage on the armature remaining constant.

(4) The relative size of motor, as referred to the maximum speed, will be directly proportional to its speed variation when using variable voltages.

(5) The relative size of motor, as referred to the maximum speed, will be as the square of the speed variation when using field regulation.

With this understanding of the matter of the use of variable-speed motors, there should be no difficulty in providing a suitable motor for any given range of speeds, providing the power required is absolutely known. Right here I want to put in a strong plea on this point. In all the applications of motors to machinery in a machine-shop, let it first be fully and positively determined how much power any individual machine or group of machines will require. Having fully determined this point, let there be no mistake made in providing a motor powerful enough to do the work. If the motor to give the necessary power and to cover a wide range of speeds, if variable speeds be desired, should

be abnormally large, gearing should be resorted to. It is far better to burden the machine with a complex set of change gears than to equip it with a variable-speed motor that will not be able to meet all the demands which will be made upon it. It is the writer's opinion, however, that it is not desirable to have speeds overlap; that is to say, that one change of gears should begin where the previous one left off, plus, of course, the change of speed due to the speed range of motor, the motor being able to fully take care of the intervening speeds. By this arrangement the operator will not be hampered by duplicate speeds, and he cannot possibly injure the motor.

## WATER REQUIRED FOR GAS ENGINES.

According to the *Engineer*, the quantity of water required at the ordinary temperature of 60° F. inlet, and 150° outlet, to keep the cylinders of gas engines cool is 4·5 to 5 gallons per indicated horsepower-hour. The jacket pipe should be from 1 to 2 inches diameter for engines up to 20 horsepower, while for larger engines the sizes are generally 2 to 3 inches for the inlet and 2·5 to 3·5 inches for the outlet. Tanks for circulating the water are generally made with a capacity for furnishing 20 to 30 gallons per indicated horsepower.

## SPONTANEOUS IGNITION OF COAL.

Alfred O. Doane, in *Engineering News*, August 18, 1904, states that, in order to reduce the danger from heating as much as possible, the following precautions should be observed. The storage bin should be roofed over. No wood should be used in its construction. The depth of the coal should be reduced as much as possible; it is best not to exceed 12 feet. All iron work, including posts, should be protected by concrete against fire and acid water from the coal. It is advisable to have a circulation of air under the bottom and around the sides of the bin or pocket.

As almost all coal will heat to some extent, it is desirable to know that the safe limit be not exceeded. This may be determined by thermometric tests. A simpler way is to drive in ⅝-inch rods at convenient places, allow them to remain a suitable time, then remove and test by the hand. An experienced man can tell by the feel if the coal is dangerously hot. If the temperature of any part of the pile is above 140° F., it is time to take active measures to prevent further heating.

When the coal in the interior of a pile ignites, the heat cokes a layer of coal around the glowing nucleus, which will shed water and make it difficult to quench by playing water on the surface of the pile. A good way is to drive in a pointed 2-inch pipe, the lower 3 or 4 feet perforated with ⅜-inch holes, to the depth of the fire as indicated by the test rod, connect the upper end of the pipe with hose, and force water into the heart of the fire.

# Mining and Metallurgical Section.

*Stated Meeting, held Thursday, April 21, 1904.*

## The Copper River Country, Alaska.

By W. R. Abercrombie, Major U. S. A.

(*Concluded from p. 310.*)

THE EFFECT OF THE CONSTRUCTION OF THE TRANS-ALASKAN MILITARY ROAD ON THE DEVELOPMENT OF AN ALL-AMERICAN ROUTE THROUGH CENTRAL ALASKA.

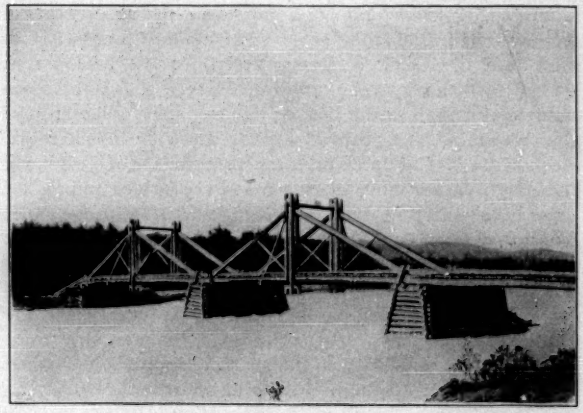
On my arrival at Port Valdez, in the spring of 1898, I found some 4,000 people that were at a loss how to proceed into the interior from the coast, owing to the lack of knowledge of the topography of the Copper River Valley. So far as any accurate information was involved, they were helpless. It was estimated that the outfits, cost of transportation and other incidentals had cost these people and their friends over $2,000,000. During the Fall of that same year over 75 per cent. of these people returned to their homes in the States with very little more knowledge of the country than they had prior to their visit, and utterly unable to explain to their friends why they had failed in their undertaking. In the Fall of 1901 the entire valley, embracing the main and sub-drainage of the Copper River, was as well known as that of most any mining district in Montana. In this interval of time the entire country had been explored, a road and bridges had been built, over which traffic could be continued during the entire season; road-houses had been built and several hay ranches located. The gross expense to the Government had been $193,000. To offset this expenditure, the prospector had taken out of the ground $185,000 of placer gold, while the discovery of copper-bearing ores bid fair to induce the investment of millions of dollars of capital, which, if it had not been for the construction of the trans-Alaskan military road, would have remained undiscovered and undeveloped for many years to come.

AGRICULTURAL POSSIBILITIES OF THE COPPER RIVER VALLEY AND ITS ATTRACTIVE FEATURES FOR THE SMALL FARMER.

Having watched for the past twenty years the growth of our former northern frontier, namely, Dakota, Montana, Idaho and Washington; having traversed the Yellowstone, Gallatin, Spokane and other valleys prior to the advent of the rancher and the railroad, I feel qualified in a measure to give an intelligent opinion relative to the capabilities of the soil and the prospects of the small farmer, who is constantly on the move in the search of a home in a new country.

I find the conditions as varying in different parts of the Copper River Valley as the great range of climatic conditions would naturally dictate. The disappearance of the snow and the sprouting of the grass varies at least forty-five days in different portions of the valley. Along almost every route that has been traveled by pack-animals will be found scattering spears of timothy and grain. I shall first consider the route traveled by the pioneer horseman of the season of 1898, as that was the only year in which pack-animals were used over the route from Valdez to Copper Center via the Valdez Glacier and Klutena River. During the season of 1899, spears of timothy and grain were found along this trail, which would indicate that the original seeding of 1898 re-seeded itself with the result of a volunteer crop in 1900, and is to my mind conclusive evidence that, when acclimated, grain and hay will both mature and bring forth abundant crops. From the evidence obtained in a small experimental garden, it is an assured fact that potatoes, turnips, beets, peas, lettuce, radishes and possibly many other vegetables will grow in abundance when the proper soil, exposure and drainage are obtained. As the existence of the small farmer is conditional on the laws of supply and demand, it will be necessary in this instance, having found the supply, to point out the probable demand. Two hundred and fifty miles inland from Port Valdez in a northerly direction lie the gold fields of the Chesna mining district, which, in my opinion, will in the next few years produce many millions of dollars of gold dust. There is to-day, aside from the 200 or 300 head of horses, the property of the

Government and individual owners, absolutely no means of transportation between these two points—Valdez and the head-waters of the Chestochena River. A pack-animal loaded with forage at Valdez, if no means of subsistence were to be had *en route*, would consume more than the forage he could pack before reaching his destination, which fact is attested by the scores of dead horses whose carcasses marked the advancement of settlement along the trans-Alaskan military road. Hay and grain to-day at Port



Queen Truss Bridge, spanning Kentena, 100 miles from Valdez, constructed with ax, auger and chisel, without nails or bolts.

Valdez, original cost and marine transportation added, will average $40 per ton. This forage cannot be transported into the Copper River Valley to the crossing of the Tonsena for less than 25 cents per pound, and then the margin to the freighter is extremely meager. Therefore, the opportunities to-day awaiting the small farmer who will select his homestead judiciously along the trans-Alaskan military road with a view of erecting thereon a bunk-house and barn for the accommodation of man and beast, and for the cultivation of forage for the animal and the vegetable product for

the man, is in my opinion so much more enticing than the inducements held out by the bleak prairies of Dakota or the wind-swept valleys of the Yellowstone as to be beyond comparison.

On this subject I would say that I am more profoundly of the opinion to-day than ever before that the valleys of the sub-drainage of the Copper River Valley will in future years supply the demand for cereals and vegetables, if not meat, of the thousands of miners who will be required to extract the vast deposits of metal from mother earth in the Chettyna, Kutsena and other districts. Referring to the available or arable land for the cultivation of forage, I shall eliminate the Coast Range entirely, for the reason that owing to the heavy fall of snow the spring is generally one month later than in the Copper River Valley. The crest of the mountains being capped as they are with monster glaciers, cause a daily precipitation from the 1st of July until freezing weather in October. While vegetables and fodder grow luxuriantly in the Coast Range district, forage must be treated as an ensilage, as owing to the constant rain it cannot be otherwise cured. Following the south fork of the Tonsena will be found thousands of acres of available land for cultivation, which, having been burnt over years ago and divested of its covering of moss, needs now only to be cleared of the dead spruce timber that encumbers it when it is ready for the plough. Five miles north of the Tonsena bridge are tracts of land well timbered and drained that is likewise available for agricultural purposes. A few miles north of the Tazlena is a stretch of sandy, loamy soil, with a southern exposure that looks attractive. At the mouth of the Tonsena River is a large hay meadow many hundreds of acres in extent, in which quantities of hay could be cured.

While the collection of information relative to the mineral possibilities of Central Alaska have been intelligently and energetically pushed forward by the U. S. Geological Survey, in my opinion the backbone of the settlement of this mighty valley—its agricultural resources—have been sadly neglected for less important researches along the coast.

COPPER DEPOSITS OF THE WRANGELL GROUP OF MOUNTAINS AND THEIR RELATION TO THE COMMERCE OF THE PACIFIC COAST.

The Copper River Valley is generally conceded by geologists to have been an ancient lake bed, the center of which was probably where now stands the colossal Wrangell group of mountains. Most prominent among the thousands of peaks and shafts that appear to pierce the very sky with their snow-clad and glacier-laden shoulders are Mounts Sanford, Drum, Blackburn and Wrangell, varying in altitude from 12,000 to 16,000 feet. The form of this group is almost a circle, drained on the north, west and south by tributaries of the Copper River; northeast by the head-waters of the Tanana; southeast by the head-waters of the White. Of the interior of this group little or nothing is known. The entire range is eruptive in character, with a central cone (Mount Wrangell) which acts as a vent for the vast furnaces many miles below in the earth's bowels. This crater is more or less active from time to time, and has, on more than one occasion in the past, rudely disturbed the surrounding country for many miles by its convulsions, when great quantities of smoke, cinders and molten lava were belched forth from its crater. During its period of repose steam jets are generally seen playing through small indicators or blow-holes on the north side of its dome-shaped crest, which, after an eruption has ceased and the lava cooled, soon becomes covered with a sheet of snow. After the mighty effort of the internal fires ages back, which push forth this mass of volcanic mountains, the cooling period followed, when the formation was rent and cracked by the reactive agents, leaving, as a result, deep and irregular canyons, exposing to view the lower levels of the formation which had originally reposed thousands of feet under the bottom of this ancient lake bed, the drainage of which is to-day the Copper River. During the earlier part of the last century the Russian Baranoff was attracted by the ingots of copper and implements of the same metal that he found in the possession of the Indians living along the Chettyna. His efforts to obtain further information, however, bore no fruit.

The next effort of any importance, so far as I am aware, was that made by the Calumet and Hecla Mining Company, of Boston, in 1898, who sent their agent, one E. J. Cooper, to search for this copper in the Chettyna country. The nearest this agent penetrated to his objective point was the mouth of the Klutena River. It is needless to say that his mission was a failure. In 1899 two plucky and resourceful prospectors induced the old chief, Nicolai, in consideration of gifts of food, to show them this location, which proved

Wagon road down Copper River bluffs to Gakona crossing.

to be a bornite deposit of great value. The richness of this copper strike, the ore of which, on being assayed, showed the presence of 85 per cent. copper, soon spread along the entire Pacific Coast.

Personally, I have traveled over more territory than any other white man in Central Alaska, which has given me the opportunity to observe the formation of the various mountain ranges and to form an opinion on this section of Alaska as a whole; in addition, I have made it a point to request of every intelligent prospector a written or verbal

report of his research. For the benefit of the public at large, I have digested these opinions, which, together with my own observations, which extend to the early periods in the mining histories of the great silver and copper camps of Colorado and Montana, based on this information I shall give an epitomized opinion of the attractive features of the mineral deposits in the Wrangell group of mountains as I have seen them. The formation of this group being circular, to more readily understand the trend of the mineral deposits, the Wrangell zone or district will be treated as a circle. The northeast segment of this circle, which is drained by the head-waters of the Tanana, is thought to be the richest portion of the zone; but owing to its great distance from seaboard and the presence of such masses of ore in the southwest division of the zone, no location, as far as I am aware, has been made there. The southeast section, which is drained by the White River, is, owing to its inaccessibility, rendered so by the crossing of Scoloi Pass, hardly worthy of consideration as a commercial proposition. Leaving the Wrangell zone for the main range dividing the Tanana and Copper Rivers, will be found quantities of copper and galena ores, although the ledges are not so massive or anything like as heavily mineralized as those in the Wrangell district, where the ledge matter is simply astounding. Ordinarily, we have been used to look upon a mineralized zone as some 10 or 20 miles in length; in the Wrangell group we have almost a circle 80 miles in diameter, the mineralization of which is simply marvelous; and yet, valuable as these concentrates are (and there must be some mighty ore deposits in this vast area of volcanic matter), they are as valueless commercially as so much sandstone without the aid of the railroad and reduction works. Low-grade ores are met with from Keystone Canyon westward; in fact, on the flood plains of Lowe River bowlders showing native copper to the naked eye can be found. If one group of mines could deflect a transcontinental trunk line, as is the case in Butte, Mont., and the great Northern Railroad, what will this mighty zone, which, considering surface indications as final, and which contains a dozen

properties of far greater value as copper propositions than have ever been mined in the State of Montana, do for the commercial interests of the Pacific Coast? If the purchase of Alaska was an epoch in the history of the Pacific Coast, the opening of Central Alaska to the general public by the War Department will be an epoch in the history of the copper-mining industry in the Western Hemisphere.

## GOLD DEPOSITS ON THE HEAD-WATERS OF THE CHESTOCHENA.

During the summer of 1898 the Chestochena River (a literal translation of the name, which is of Indian origin, being "the river that rises among the Red Mountains") was reported to have fine gold in considerable quantities among its gravel. In September, 1899, I met two prospectors by the name of Hazlett and Meals, who had built a cabin and spent the winter on the Chesna, a branch of the Chestochena, in the mountains up near its source. From these men I learned that not only was there fine gold, but coarse gold, and in paying quantities. They had given the Chesna quite a thorough test with the result of demonstrating the existence of placer gold on all tributaries to the Chesna, and had followed the pay streak down the Chesna for some 7 or 8 miles to a point about a mile above its confluence with the Chestochena; there they had located a number of claims.

I made a thorough examination of the Chesna mining district into which prospectors had organized all tributaries of the head-waters of the Chestochena. It was found that not only did the Chesna and the small creeks at its head contain placer gold, but that Slate Creek, which is likewise tributary to the Chestochena, some 12 or 14 miles above the confluence of the Chesna and Chestochena, as well as Big Four and Buena Vista Gulches, were rich in placer gold. The country is extremely mountainous, the mountain sides being stained with immense brilliant red blotches of oxide of iron that shade off through yellows to a light gray. Some 5 miles up the Chesna, coming in from the left, is a small creek christened by the miners "Gold Creek," not on account of the gold, however, which it contains, but owing to the

brilliant coloring of the rock through which it has cut its stream's bed, which is the most gorgeous I have ever seen in the mountains. The water in the first place is as clear as crystal. The little canyon out of which this stream rushes has been worn away for half a mile or so, leaving the water to plunge over a sheer wall of this brilliantly colored rock 75 or 100 feet high. The refraction of light through the water from the highly colored rock makes it glitter and sparkle like gold; but curiously enough, the oxide formation appears to have nothing to do whatever with the auriferous deposits. Following up the Chesna to Meadow Creek, the oxide formation is crossed and a dull black slate formation encountered. Meadow and Ruby Creeks average from 1½ to 2 ounces per day to the man with five lengths of sluice boxes, and from an examination of the tailings I am satisfied that quite a bit of the gold was carried through the boxes.

Over a low divide from the head of Meadow Creek, not more than 1,000 yards, is Slate Creek, a barren, bleak, desolate-looking watershed. The gravel in the creek is dull and dead-looking—the last place one would look for gold deposits. The creek contains about sixteen full claims of 20 acres each. The discovery was made about the 19th of June, 1900, and from its gravel between July 10th and August 1st was washed out some $18,000 in gold dust. When I arrived there on the 15th of August, so slight an impression had the miners made on the face of the bars of the creek bed in taking out this gold that I was unable to find the ground that they had sluiced over until it was pointed out to me. On Miller Gulch, a small branch of the main creek, midway between its source and mouth, I tested the ground from the top of the mountain, which is about 2,000 feet above the creek bed, to the base, and was astonished to find pay dirt that would run from 15 to 20 cents a pan on the tops of these mountains.

In going down the mountain side the gold did not appear to be any coarser than that on the summit. In the face of a little cut bank on the side of this creek the dirt appeared to be peppered with fine gold to a height of some 9 or 10 feet above running water.

From a spot not larger that my hand, three nuggets were picked out, the largest weighing almost a dollar. Just below the bank, four men took out in ten days a grub stake of $1,000 each from an area not larger than that of the body of a wagon. The richest panful of dirt I am told ran a little over $6. Should the gold grow coarser as bedrock is reached, this deposit will be marvelously rich; but judging from the fact that the surface indications of the creek bed on the higher benches and the mountain tops carry about the same grade of gold as to coarseness, I am inclined to think that the Slate Creek deposits do not represent the main or coarse gold deposits. On the north side of the range from Miller Gulch are Buena Vista and Big Four Gulches, with precisely the same character of gold. At the mouth of Slate Creek, I found a number of location notices that had been made there by amateur prospectors in the summer of 1898.

Had these men been possessed of a little practical knowledge in placer mining, they would have found at a distance up the creek, not to exceed 2 miles, a short piece of rim rock that would have disclosed the fact to them that coarse gold was in the gulch. For the information of just such persons, who toil and labor with sled and boat simply to turn their backs on a fortune, I will state just how the professional prospector hunts for ear-marks or indications of the presence of gold in a mountain range. The formation (and by that I mean the presence of porphyry, slate or granite) does not materially aid the prospector in his research, as upheavals and a thousand other metamorphic conditions so change the rugged features of mother earth in 10,000 years that the original source from which the gold came has probably disintegrated and washed away thousands of years before the prospector came on the scene. As I have said, the professional prospector selects a long, swift stretch of water that shoots or sweeps all gravel from its rocky bed. In the course of time this stream cuts down through its rocky bed, leaving a rim or bank of rock on each side that, from exposure to the air, becomes more or less fractured, and into these fractures seeps moisture, which the frost

congeals, prying the fractures slightly apart, and the melting snow from year to year in its rush down this rocky canyon carries with it detritus, in which there is placer gold, should there be any on the mountain sides above; into these crevasses of the rim rock sooner or later drops one of these fine particles of gold, its specific gravity being so great that it soon buries itself in the fracture. The skilled prospector selects a favorable place in the rim rock, and with the end of his pick prys open the fracture, places the rock in his gold pan, and washing the mud therefrom with his hand into the gold pan, discovers the small grain of gold that has been lodged there by nature in complying with the laws of gravitation. This is termed rim-rock prospecting, and simply indicates the presence of gold in more or less quantities in the gulch above, and its discovery is called a "prospect," or the gulch is said to prospect.

THE NECESSITY FOR A TRANS-ALASKAN RAILROAD FROM THE ONLY OPEN-WINTER PORT IN ALASKA NORTH OF THE LYNN CANAL TO THE YUKON VALLEY.

In a report submitted by me to the Honorable Secretary of War in 1899 was one bearing on the practicability of the construction of a railroad from tide-water at Port Valdez to the Yukon River. In this report, Mr. Gillette, my locating engineer, gave in detail the grade, curvature and cost per mile from tide-water to Thomson Pass, the assumption at that time being that the saving in mileage of a main line *via* Thomson Pass, China and Knata Rivers would more than offset the extra cost of tunneling, etc., incident to this pass. Since the discovery, however, of vast deposits of copper in the Wrangell Range and the presence of other minerals in the Brenner and Consena countries, I am in favor of the route *via* Marshall Pass for the following reasons: The gradient over Marshall Pass and down the Taznuna River is nominal; the divide itself is but 1,700 feet in altitude, with an approach to and departure from it that is absolutely devoid of engineering features. This pass will connect the Copper River Valley with tide-water by a grade of not to exceed 1 per cent., is entirely free from glaciers and snow-

slides, is about 47 miles from tide-water at Valdez to the banks of the Copper River, where the Taznuna empties its water into the latter river.

As a temporary measure in opening up the great copper deposits in the Wrangell group of mountains, river boats and scows as a means of transportation for "ore" could be utilized from the mouth of the Taznuna as high up the Copper River as the lower canyon of the Chettyna, and to the rapids about 10 miles below the mouth of the Tonsena.

From the mouth of the Taznuna to Woods Canyon there

Wagon road north of Gakona, 170 miles from Valdez.

is little or no rock-work along the banks of the Copper, the construction work being almost exclusively a side hill cut with few fills. Swinging to the left on reaching Woods Canyon, a short climb of not to exceed 2 per cent. is made for a distance of probably 2 miles, when the summit of an elevation, that I should imagine does not exceed 1,000 feet, is crossed, and the line again drops down to the river. Following up the river a distance of some 18 miles is a possible site for a bridge for a feeder to accommodate the traffic from the Chettyna and the Kotsena mining districts.

Following up the course of the Copper River from this point the work would be featureless, simply grading and filling to the crossing of the Tazlena, where the line would probably leave the Copper River bed, and taking a northeast tangent, pass over a flat, densely timbered plateau to the crossing of the Tanana.

Down this stream some 60 miles, a feeder would reach the end of the Bates Rapids, encountering in construction little or no rock work.

From this point below Bates Rapids, river steamers can ascend and descend from the Yukon at any stage of water. After crossing the Tanana, an easy stream to bridge, the projection of a line is simply a matter of detail in location. From the crossing of the Tanana, south, a 50-mile feeder would connect the main line with the mineral deposits on the headwaters of the White and Tasuna.

From Keystone Canyon to Woods Canyon, tie timber is scarce, the mountain sides being covered almost exclusively with a dense growth of alder. From Woods Canyon to the crossing of the Tasuna, tie timber may be had *en route* in abundance, while in favorite places ample supply of bridge timber can be cut.

As far as the feasibility of a route for the construction of a trans-Alaskan railroad is involved, free from international complications, there is absolutely no question but that there is one route from a seaport that may be entered any day in the year by ocean-going steamers, to connect with a railroad system over an "all-American route" to the Yukon Valley, and that seaport is Valdez.

## FEEDERS TO THE MAIN LINE.

If I am correctly informed, the southwest section of the Wrangell group of mountains will, just as soon as transportation facilities offer the opportunity to the miner to move his ore from the mine to the seaboard, furnish thousands of tons of freight per day. I have carefully gone over the ground with both railroad and mining engineers of experience, and am satisfied that the copper deposits of Mount Vlakeburn alone will support 200 miles of road, the

construction of which I place at $14,000 per mile, exclusive of bridging the Copper River.

The Bates River branch would tap the placers of the Keokuk and that portion of the Yukon west of Circle City by the steamers of the river route now established. The White River feeder would tap the mineralized zone of copper and other metals of the northeast district of the Wrangell group of mountains, while the trade of Birch Creek, Forty Mile and other districts, to say nothing of the Chestochena country, would all pay a local tonnage to the main line. I believe that the local tonnage would be of such a volume as to not only earn for such a road a liberal return for the construction bonds, but also, in addition, allow the operators to maintain such a thorough rate of traffic, from the seaboard to the Yukon Valley, as to preclude any attempt to supply that valley *via* a longer and less favored route from the Pacific Coast.

During the subsequent years of 1900 and 1901, followed the construction of the trans-Alaskan military road by me from Port Valdez to the Yukon River, with its docks and bridges, detailed information of which will be found in my reports to the War Department from 1898 to 1901.

It was the construction of this road and the gathering of the information demonstrating the existence of a natural location for a railroad far superior to that through the Canadian Territory, which aided materially the adjustment of the international complications between the United States and Canada relative to the boundary line at the head of the Lynn Canal, the details of which would require volumes.

It is seldom given a man to witness the results of the developing of a country that he has explored, and I take not a little satisfaction in looking back to the earlier stages of my struggle to untangle a small part of this wilderness.

# PHYSICAL SECTION.

*Stated Meeting, held Thursday, April 23, 1904.*

## A Proposed Modification of the Perfect Heat-Engine Formula.*

By Louis Illmer, Jr.

According to the first law of thermodynamics, which is based upon the indestructibility of energy, the maximum amount of work which can be produced by means of a heat engine, is equal to the difference between the heat absorbed and the heat discharged by the engine. During transformation an amount of heat equivalent to the work performed must necessarily disappear, hence:

$$W = H_1 - H_2 \qquad (1)$$

where $W$ = heat intercepted and converted into available work by the engine.

$H_1$ = unstable heat supplied to the engine as measured in foot-pounds.†

$H_2$ = unstable heat discharged from the engine.

By simple transformation of factors the above equation may also assume the following form:

$$W = \left(1 - \frac{H_2}{H_1}\right) H_1 = \left(\frac{W}{H_1}\right) H_1 = E \,.\, H_1 \qquad (2)$$

where $W \div H_1 = E$ = thermal efficiency, which is the ratio of the thermal equivalent of available work done to the amount of unequalized heat demanded by the engine to produce that work.

The numerical value of the efficiency factor $E$ for specified conditions, cannot actually be determined from equation (2), because the first law of thermodynamics does not state

* Read by title.

† For the sake of mathematical simplicity, heat energy will be measured in foot-pounds throughout this article so as to eliminate the factor for the mechanical equivalent of heat.

definitely, whether or not, the entire amount of heat supplied to a perfect engine can be fully converted into useful work; that is, the first law does not render a fixed value for the factor $H_2$. The first law simply declares that heat and work are mutually transformable in one definite and constant ratio of conversion and that when heat is transformed into work, the transformation will necessarily take place in such a manner that energy is neither created nor destroyed. As will be shown later, it is actually impossible to completely convert heat into *available* work.

Viewing equation (2) from a mathematical standpoint, it at once becomes evident that there are two unknown factors in a single equation; $W$ is given as a difference of $H_1$ and $H_2$, but since the ratio between $H_1$ and $H_2$ is not definitely fixed, an infinite number of pairs of values can be found which satisfy the equation. In order to eliminate one of the two unknown factors, another equation must be derived which directly or indirectly fixes the relation between the two independent variables. This required second equation may be regarded as a mathematical statement of the second law of thermodynamics.

The second law is based upon the fact that not all conceivable transformations of energy, which comply with the first law of thermodynamics, can actually occur. Both experience and scientific analysis show clearly that only a certain definite portion of heat energy can be converted into useful work. Heat transformations must necessarily be impelled by some form of instability because only the *unstable* part of heat energy is capable of changing its own condition. Unstable heat represents *potential* difference and is measured by the *unequalized* portion of heat energy in any particular system.

The classification of energy into stable and unstable energy, corresponds, respectively, to Helmholz's bound and free energy. A mathematical factor which measures the instability or intensity head of energy can readily be derived from the following fundamental equation which denotes the equivalence of potential and kinetic energies:

$$w\,h = 1/2\,M\,v^2 \qquad (3)$$

where $h$ = height from which body must fall towards the earth in order to acquire a velocity $v$.

$w = M g$ = weight, which is a measure of the force of gravity acting upon a body whose mass is $M$.

$M$ = mass or the *quantity* factor of force—mass is the capacity of a body of absorbing and storing force.

$g$ = uniform acceleration of gravity—acceleration is *intensity* factor of force.

$1/2\, M v^2$ = kinetic energy.

$w h$ = potential energy.

Equation (3) may also be factored as follows:

$$M \,.\, g h = M \,.\, \frac{v^2}{2} \qquad (4)$$

where $g h$ = *intensity* factor of potential energy—an intensity of force multiplied by the distance through which that intensity is capable of acting.

$\frac{v^2}{2}$ = corresponding kinetic intensity.

The above equation shows plainly that energy may be thought of as constituting of two principal factors—a *quantity* or *capacity* factor $M$ and a *quality* or *intensity* factor $g h$ or

$$\frac{v^2}{2}.$$

This important deduction necessarily applies to all forms of energy.

Since heat, considered from the kinetic standpoint, is believed to be a mode of invisible molecular motion, the above deductions as to intensity and extensity must also apply to heat energy. The absolute quantity of sensible heat in a unit volume of any body must then be a function of such molecular motions as produce heat effects. It can be shown that

$$Q = 1/2\, M\, G^2 = D \,.\, \frac{G^2}{2} \qquad (5)$$

where $Q$ = *absolute* sensible heat energy in a unit volume of gas as measured in foot-pounds.

$D = M$ = density of the gas or mass per unit volume.

$G^2$ = mean square of the molecular velocities as measured from the absolute zero of velocity.

By analogy, it immediately becomes apparent that one-half of the mean square of the molecular velocities is the *absolute* intensity factor of heat energy; accordingly we have:

$$\frac{G^2}{2} = g\,h = C\,T \qquad (6)$$

where $C$ = a constant factor of proportionality.

The absolute intensity factor of heat energy $T$ is defined as absolute *temperature*. It measures the absolute thermal potential of heat energy with respect to the absolute zero of temperature, whose numerical value is about 293° C. below atmospheric temperature. The absolute zero represents that fixed point at which all matter is supposed to be totally destitute of heat energy.

Equation (5) also shows that heat energy contains another factor which is independent of temperature, namely, an *extensity* or mass factor, as will be more readily understood by substituting for $G^2$ as follows:

$$Q = D \cdot \left(\frac{G^2}{2}\right) = D\,(C\,T) \qquad (7)$$

Temperature as measured in degrees is an arbitrary unit, hence the constant $C$ must be introduced in the above equation so as to bring the temperature factor $T$ into absolute units. Considered rationally, the intensity factor of heat energy ought to be taken as $C\,T$ and not simply as $T$. In practice, however, it is desirable to combine all constants of proportionality into the extensity factor. By the rearrangement of the constant $C$, equation (7) finally takes the following form, which applies to both latent and sensible heat energies:

$$Q = (D\,C)\,T = \phi \cdot T \qquad (8)$$

where $T$ = absolute temperature as measured in degrees from the absolute zero.

$D\,C = \phi = \frac{Q}{T}$ = a factor proportional to the mass factor of heat energy.

$D$ = density or rational mass factor for heat energy.

Clausius has given the name of *entropy* to the modified thermal extensity factor $\phi$; entropy may be considered as a sort of heat weight or heat volume, as shown by Zeuner.

The product of temperature into entropy as a measure of heat energy corresponds to the product of absolute pressure into volume as a measure of the potential energy in a confined gas, or to the product of voltage into current as a measure of electrical energy.

Since the total energy of an isolated system must necessarily remain constant, the numerical value of the product of the quantity into the quality factor cannot in any way be effected by the mutual actions of the forces which compose a confined system. In an isolated system of forces, an increase in one of the energy factors without a corresponding decrease in the other factor would imply either the creation or the destruction of energy. The extensity factor of energy may, however, increase at the expense of the intensity factor, and for certain forms of energy the intensity factor may also increase relative to the extensity factor.

The mutual interchange of the energy factors, relative to each other in both directions, is a property only of the so-called ordinate energy. Energy may exist in either the ordinate or the inordinate form. Ordinate energy is the result of periodic or organized motion, and is at all times under *direct control*. The ordinate forms of kinetic energy, as for instance mechanical or electrical energy, are destined to pass into the "more probable" inordinate or heat form of energy.

The motion which constitutes true *inordinate* energy takes place in all conceivable directions and can be produced only in a medium consisting of infinitely small particles. Inordinate or disorganized motion is *not* directly controllable; due to incessant molecular bombardment, inordinate motion tends to change of itself in such a manner as would equalize the different degrees of intensity of molecular motion.

Such energy inherently tends to increase its extensity factor, but cannot increase its intensity factor at the expense of the extensity factor without compensation of potential.

Sensible heat is naturally a form of inordinate kinetic energy, because due to continuous impact, the molecules of a hot* gas necessarily travel in every conceivable direction. The separate molecules of a hot gas, when in a state of equilibrium, travel in such a manner that the sum of all the component velocities in any one direction is equal to the sum of the component molecular velocities in the direction exactly opposite. The resultant velocity of the center of gravity of a hot gas in equilibrium is therefore equal to zero. Hence, in analyzing motion of this kind, it is necessary to discriminate between the motion of the individual molecules of a hot gas and the motion of the center of gravity of all the molecules. The latter is a resultant motion.

Inordinate motion cannot be retarded directly, but if, by some means, a portion of the molecules of a hot gas can be made to travel continuously in any one definite direction, it will completely convert a corresponding portion of the inordinate energy into the ordinate form, and thereby set the common center of gravity of the molecules in motion. By interposing a resistance to such progressive rectilinear motion, the mechanical energy of the moving mass of gas, now under control, can readily be transferred to other bodies. This primitive process of transformation is one of the simplest methods for converting the irregular or zig-zag motions of heat ino mechanical energy.

We have no direct control over the direction of disorganized molecular motions of a hot gas which is confined to a definite volume; inordinate motion can, however, be controlled indirectly by *change* of volume. Furthermore, only those gases which are in a state of unstable equilibrium are capable of changing their own volume. Hence, since instability measures the power with which a gas tends to expand, inordinate molecular motions can simply be made to rectify

* Throughout this article the term "hot" gas refers especially to one possessing a temperature head with respect to the atmosphere.

themselves in direct proportion to the *unequalized* heat energy residing in the working fluid.

For the conversion of inordinate into ordinate energy, and subsequently for the conversion of ordinate energy into work, we need consider merely that portion of the inordinate energy which is under control; in any case the controllable portion of energy is equal to the *unequalized* portion of heat energy of the system as determined by a *relative* standard of measurement. For heat energy transformations, the mean atmospheric temperature should be taken as the standard by which to measure relative potential or temperature heads. The thermal capacity of the atmosphere may be regarded as infinitely large when compared with that of a limited quantity of isolated working substance. The effect of this assumption is that all thermal energy tends to approach the atmospheric temperature.

When the unequalized intensities in the different parts of a heat-energy system finally become perfectly uniform throughout, such heat energy must forever remain in the equalized state unless the system as a whole still possesses a thermal *potential* with respect to some external system. Completely equalized heat energy is said to be in a state of *stable* equilibrium, and its availability is permanently lost. In analyzing thermal phenomena, it is necessary, therefore, to distinguish carefully between an absolute and a relative potential head.

The work which a hot gas can be made to do is directly proportional to the degree to which molecular motions can be absorbed by converting a portion of the heat into another form of energy. As has already been stated, inordinate molecular motion (heat energy) can be controlled indirectly when a temperature head is available; not until the zero of reference could be maintained at the absolute zero, *i. e.*, about 500° F. below atmospheric temperature, would it be possible to fully convert the entire or absolute heat residing in a hot gas into useful work. Under these conditions all molecules could be brought to a state of rest.

The corresponding mechanical analogy is quite simple. The motion which we ordinarily consider in equations for

mechanical energy is actually a relative and not an absolute motion. Due to the rotation of the earth, all bodies on its face really have an exceedingly high velocity with respect to an absolutely stationary body in space; in consequence, the absolute velocity of any body on the earth's surface is actually very much greater than that due to its measurable relative motion.

It is quite as impossible to convert the entire or absolute heat energy of a hot working substance into work when the temperature of reference is that of the atmosphere, as it is to utilize the entire or absolute motion of a body without being in a position of absolute rest in space.

When, however, the atmospheric temperature is considered as an arbitrary zero of reference for relative temperatures, in the same way that the motion of the earth's surface is ordinarily assumed to represent the state of so-called rest for mechanical motion, then the *unequalized* heat energy residing in any working substance can be completely transformed into work for exactly the same reason that the available mechanical energy of a body can be fully transformed into heat.

At atmospheric temperature, a working fluid contains within itself a certain amount of potential and kinetic energy with respect to the *absolute* zero temperature; such intrinsic thermal energy cannot possibly be converted into available work because the working substance possesses no relative potential with respect to the atmospheric temperature. Accordingly, the equalized or intrinsic thermal energy of a working fluid cannot in any way affect the final efficiency of a heat transformation.

In order to find the proportion of heat which can actually be converted into work, it is positively necessary to separate the absolute heat into stable and unstable energy.

The unequalized portion of the absolute heat residing in a working substance can readily be determined by transferring the zero of reference from the absolute zero to atmospheric temperature. It is essential that the mean atmospheric temperature be taken as the zero of reference; any other temperature would not completely separate the

absolute heat energy into equalized and unequalized heat energy.

According to the foregoing discussion we have:

$$H = Q - Q_o \tag{9}$$

where $H$ = the *unequalized* heat energy in a unit weight of working fluid as measured from the mean atmospheric temperature.

$Q$* = total or absolute heat energy in a unit weight of working substance; it includes both sensible and latent heats.

$Q_o$ = intrinsic or stable heat energy in a unit weight of working substance at atmospheric temperature. The numerical value of the constant $Q_o$ is ordinarily indeterminable.

Transforming and substituting the value of $Q$ as given by equation (8),

$$Q = \phi \,.\, T = H + Q_o \tag{10}$$

Differentiating, we have:

$$d\,Q = \phi \,.\, d\,T + T \,.\, d\,\phi = d\,H + O$$

Confining this equation to *unit* weight of working substance, the extensity factor $\phi$ will be a constant, *i. e.*, $d\,\phi = O$, and, therefore, the above equation reduces to:

$$d\,H = \phi \,.\, d\,T.$$

Finally, integrating between the limits of temperature $T_1$ and $T_o$, we have:

$$H = \phi\,(T_1 - T_o) = \phi \,.\, t_1 \tag{11}$$

where $T_o$ = atmospheric temperature as measured on the absolute scale

$(T_1 - T_o) = t_1$ = temperature head of the working substance as measured with respect to atmospheric temperature.

The quantity of available heat, $H$, residing in a unit weight of working substance, is directly proportional to the

*The quantity $Q$ must not be confounded with the heating value of a fuel. The heating value of coal, for instance, measures the available potential or unstable energy in a pound of coal; it should properly be designated by $H$.

temperature *head* existing between such a hot body and the surrounding atmosphere.

Carnot, the originator of the thermodynamic cycle, states this principle in a somewhat different form:*

"Heat alone is not sufficient to give birth to impelling power; it is necessary that there shall be cold; without it heat is useless."

The one essential requirement for the conversion of heat into work is initial temperature difference or thermal instability. When the temperature head of thermal energy finally becomes equal to zero, so that heat can no longer be transferred to colder surrounding bodies, *i. e.*, the atmosphere, such heat must remain in the form of heat, and cannot further serve for the production of useful work. In this condition the fully equalized heat energy has reached a state of stable equilibrium, and no longer tends to change its form.

Having shown that only the unstable portion of the total energy $Q$ can be converted into work, we must now determine what portion of such mechanical energy can actually be converted into *useful* work. A part of the absolute work of expansion is necessarily absorbed and rendered latent in displacing the atmosphere.

Ordinarily the thermodynamic formulæ for work done during expansion, do not discriminate between useful and the unavailable displacement work, but simply measure total or absolute work. The net or available work of expansion can readily be found as follows: Let $P$ denote the total absolute pressure in pounds of the gas confined within a cylinder and let $P_o$ denote the total absolute pressure in pounds of the atmosphere resisting the piston motion; then,

$$d\,W = (P - P_o)\,d\,V \qquad (12)$$

where $W$ = available or resultant positive work of expansion as measured in foot-pounds.

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*Carnot: "Reflections on the Motive Power of Heat." Translated from the French by Dr. R. H. Thurston.

$dV$ = change in volume of the working substance as measured in cubic feet.

$P \cdot dV$ = total or absolute work of expansion as measured in foot-pounds.

$P_o \cdot dV$ = unavailable or negative work of expansion as measured in foot-pounds.

The effective work produced by a perfect gas when expanding from an initial volume $V_1$, to a larger volume $V_2$, can be determined by substituting the characteristic value for $P$ in the above equation.

For isothermal expansion of a perfect gas $PV = C =$ a constant, hence;

$$W = C\int_1^2 \frac{dV}{v} - Po\int_1^2 dV$$

$$= C\log_{.e}\frac{v_2}{v_1} - Po\,(v_2 - v_1)$$

$$= C\log_{.e}\frac{P_1}{P_2} - Po\,(v_2 - v_1 \qquad (13)$$

where $W$ = external work which would actually have to be done upon the gas in order to re-establish the original volume $v_1$ by means of isothermal compression.

$C\log_{.e}\frac{v_2}{v_1} = C\log_{.r} =$ total or absolute work of isothermal expansion.

$r = \frac{v_2}{v_1}$ = ratio of expansion.

$Po\,(v_2 - v_1)$ = latent work done in displacing the atmosphere. This stored work may be refunded to the working fluid in the form of sensible heat during compression.

Since both the temperature and the mass factor of the working substance remain constant during isothermal expansion, the entire unstable heat supplied to a perfect gas is fully converted into work, *i. e.*

$$H = C\log_{.e} r = W + Po\,(V_2 - V_1) \qquad (14)$$

where $H$ = the uneqalized heat supplied to the working substance as measured in foot-pounds.

Equation (14) shows that only a certain portion $W$ of the unstable heat $H$ can be converted into useful or *available* work. The production of a large proportion of available work from a given amount of unstable heat, requires a relative reduction in the displacement work. This condition is satisfied when a comparatively high mean effective pressure of expansion is maintained with relation to the atmospheric pressure.

If, on the contrary, expansion is unduly extended so as to allow the pressure of expansion to fall below atmospheric pressure, the negative displacement work will exceed the corresponding positive work of expansion and accordingly result in the predominance of negative work, as shown by the shaded area $B$, in *Fig. 1.* No available work can be secured from heat energy by expanding below atmospheric pressure when the resisting pressure is that of the atmosphere. This important principle can be incorporated in equation (13) by limiting the final pressure $P_2$ to the atmospheric pressure $P_o$, thus,

$$W = C \log_e \frac{P_1}{P_o} - P_o (V_2 - V_1) \qquad (15)$$

This equation represents the greatest amount of *available* work which can be produced by direct isothermal expansion of a perfect gas whose initial pressure and volume are $P_1$ and $V_1$, respectively. Equation (15) shows, furthermore, that it is impossible to *fully* convert heat into effective work. In so far as this deduction is based upon the assumption that $P V = C$ during isothermal expansion, it applies to the perfect gas only.

It can be shown, however, that a similar conclusion also applies to the imperfect gases. But in order to eliminate the indeterminable amount of energy, which is demanded to separate the molecules of an imperfect gas during expansion, a rigorous proof of the corresponding analysis requires the adaptation of a series of cyclic processes. A cycle permits the successive re-establishment of the initial conditions of temperature, pressure and volume of the working substance by means of alternate expansion and contraction. All the work produced by a cycle of this kind will be due

solely to the heat supplied to the engine and is not in any way dependent upon the intrinsic heat energy residing in the working fluid.

Before deducing formulæ for the different thermodynamic cycles, it is necessary to ascertain the essential conditions for the realization of *maximum* efficiency.

Every heat energy transformation must be impelled by a potential difference; conversely, every heat energy change which can take place of itself is capable of rendering a definite amount of work when properly utilized. For perfect transformation, the unstable heat energy lost during transformation must be fully recovered by available energy of another form so as to maintain the instability of the system constant throughout the transformation.

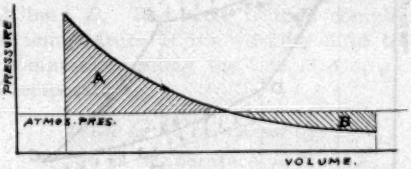


FIG 1.

Carnot summarizes these ideas in the following significant quotation:

"Since every re-establishment of equilibrium may be the cause of the production of motive power, every re-establishment of equilibrium which shall be accomplished without the production of this power should be considered as an actual loss. Reciprocally, every time this condition is fulfilled, the maximum will be attained."

In other words, the above thermodynamic principle implies a perfectly reversible process or cycle such that the initial physical and thermal conditions, which the working substance possessed before transforming a given portion of its heat into work, can be completely re-established.

A certain amount of available motive power will be permanently lost whenever the source of heat is wholly, or even

partially, allowed to come in direct contact with the refrigerator. Such a cycle cannot, therefore, be perfectly reversible. The primary theoretical requirement for a cycle of maximum efficiency is that the working substance must have an infinitesimal difference of temperature from that of the source while receiving heat and a similar difference of temperature from that of the refrigerator while discharging heat. Consequently the temperature of the working fluid must be reduced by some means from $T_1$, the temperature of the source, to $T_2$, the temperature of the refrigerator, so that the waste heat can be discharged without loss of unstable energy.

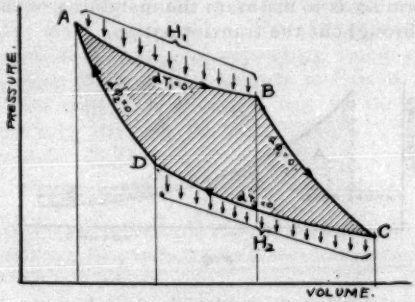


FIG. 2.

It can readily be proved that the work produced by a perfect heat engine is due simply to the difference of the works represented by the isothermal lines. It is immaterial, theoretically, in which manner the temperature of the working substance is reduced from the temperature $T_1$ to $T_2$, provided only that precisely the same quantity of energy is refunded to the working fluid while raising its temperature as was previously stored while lowering it.

This process of temperature reduction may involve the storage of heat in the form of work by means of adiabatic expansion, as in the Carnot cycle; or it may involve the storage of heat energy in the form of heat by means of a regenerator, as in the Stirling cycle; and for the more com-

plicated case, as in the Ericsson cycle, a combination of the two methods may be employed. Theoretically, the thermal efficiency of all three cycles is the same.

The perfect cycle consists essentially of a source of heat, from which heat energy is abstracted by the working substance at one constant high temperature, and a refrigerator into which waste heat may be rejected at one constant low temperature. The Carnot cycle is bounded by a set of isothermal and adiabatic lines and is, therefore, a perfectly reversible cycle.

Referring to *Fig. 2*, heat is admitted into the engine cylinder, at a temperature $T_1$, along the isothermal line $A\,B$. The temperature of the gas is reduced to the lower limit $T_2$ by means of adiabatic expansion along the line $B\,C$. The waste heat is discharged into the refrigerator along the isothermal line $C\,D$. The cycle is then completed by elevating the temperature of the working fluid by means of adiabatic compression along the line $D\,A$ so as to restore the initial temperature.

*Formulæ for the Carnot Cycle.*

Range of temperature $= T_1 - T_2$.

Unequalized heat supplied:

Along $A\,B$ at constant temperature $T_1$.

$$= H_{ab} = R\,T_1 \log_e \frac{V_b}{V_a} \qquad (16)$$

Unequalized heat discharged:

Along $C\,D$ at constant temperature $T_2$.

$$= H_{cd} = R\,T_2 \log_e \frac{V_c}{V_d} \qquad (17)$$

Adiabatic expansion along $B\,C$; $(H_{bc} = 0)$;

Adiabatic compression along $D\,A$; $(H_{da} = 0)$.

*Production of Available Work of Expansion:*

Along isothermal $A\,B$

$$= W_{ab} = P_a V_a \log_e \frac{V_b}{V} - P_0(V_b - V_a)$$

Along adiabatic $B\,C$

$$= W_{bc} = K_v(T_b - T_c) - P_0(V_c - V_b).$$

*Consumption of Available Work During Compression:*

Along isothermal $C\,D$

$$= W_{cd} = P_c V_c \log._e \frac{V_c}{V_d} - P_o(V_c - V_d)$$

Along adiabatic $D\,A$

$$= W_{da} = K_v(T_a - T_d) - P_o(V_d - V_a).$$

Since the difference of temperature between the two isothermal lines is constant, we have,

$$(T_b - T_c) = (T_a - T_d) = (T_1 - T_2)$$

also,

$$\left(\frac{V_d}{V_a}\right)^{k-1} = \frac{T_1}{T_2} = \left(\frac{V_c}{V_b}\right)^{k-1}$$

therefore,

$$\frac{V_b}{V_a} = \frac{V_c}{V_d} = r = \text{ratio of expansion.}$$

These qualities show that the work of adiabatic expansion is equal to work of adiabatic compression. The displacement work is eliminated by subtraction and hence the formula for the resultant *available* work takes the following simplified form:

$$W = W_{ab} + W_{bc} - W_{cd} - W_{ad}$$

$$= P_a V_a \log._e \frac{V_b}{V_a} - P_c V_c \log._e \frac{V_c}{V_d}$$

$$= R(T_1 - T_2) \log._e r = H_{ab} - H_{cd}. \qquad (18)$$

Finally, the theoratical thermal efficiency of the perfect heat engine is,

$$E = \frac{W}{H_{ab}} = \frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1} \qquad (19)$$

where $E$ = thermodynamic efficiency of the perfect heat engine—perfect in the sense that no other heat engine can be more efficient thermally when working between the temperature limits $T_1$ and $T_2$.

$T_1$ = absolute temperature of the source of heat.

$T_2$ = absolute temperature of the refrigerator.

$\frac{T_2}{T_1}$ = ratio of the unequalized heat discharged to the unequalized heat supplied to the engine; it represents the fractional loss of potential during transformation.

During expansion, the heat supplied to the engine is only partially converted into available work, but during compression the consumption of available work apparently more than produces its equivalent of heat, because the latent displacement work also assists in compressing the gas.

The restoration, during compression, of the displacement work in the form of heat energy, increases the heat discharged from the engine; this, in turn, reduces the thermal efficiency of the cycle. The latent displacement work is really similar in its effects upon thermal efficiency to re-evaporation in the steam engine. Consequently, to produce a certain amount of available work by means of a perfect engine, it is necessary to add not only enough heat to produce the available work $W$, but also an additional amount of heat sufficient to compensate for the inapplicable displacement work. The characteristic manner in which the latent displacement work increases the discharged heat $H_2$, involves a permanent loss of availability of motive power and the law of dissipation of energy follows as a natural consequence.

As the stored displacement work cannot possibly be recovered in the form of available work, the efficiency of conversion of heat into available work can never reach unity. For maximum efficiency, we should endeavor to retain a maximum amount of available work of expansion by restoring the initial conditions of the working substance with a mimimum expenditure of compression work. At first sight it appears as though a cycle, in which heat is discharged at constant pressure, may be more efficient than one in which heat is discharged at constant temperature; a little reflection will show, however, that when heat is discharged at a constant pressure, it suffers a useless temper-

ature drop, which is contrary to the condition of maximum efficiency.

To produce the maximum amount of work, all the heat must be absorbed by the working fluid at the highest temperature possible, and in order to reduce the heat discharged to a minimum, all the heat must be abstracted from the working substance at the lowest temperature possible. The highest temperature available is limited by conditions of combustion, while the lowest temperature is limited to atmospheric temperature.

If expansion were continued to such an extent as to reduce the temperature of the working substance below that of the

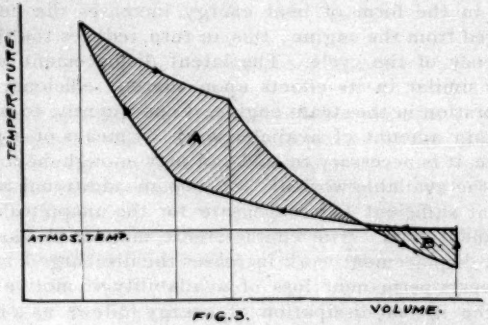


FIG. 3.

atmosphere, it would be impossible to discharge the waste heat from the engine directly into the atmosphere, because such heat would possess no positive temperature head with respect to the atmospheric temperature. In case the working substance is heated at the termination of expansion, so as to acquire the temperature of the atmosphere, before isothermal compression begins, as shown in *Fig. 3*, the effective work done will be equal to the difference of the positive area *A* and the negative area *B*. Unduly extended expansion, therefore, increases the heat discharged into the refrigerator and actually involves a loss of effective work. Increased expansion necessarily results in

decreased efficiency when the continued expansion reduces the temperature of the working fluid below that of the atmosphere.

As shown by equation (17), the unstable heat discharged from an engine is equal to the product of the absolute temperature of discharge $T_2$ into the natural logarithm of the ratio of expansion $r$. For insufficient expansion, the factor $H_2$ will be large on account of the excessive value of the factor $T_2$. If, on the contrary, the expansion is increased unduly so as to reduce either the temperature or the pressure of the working substance below that of the atmosphere, the heat discharged from the engine will likewise be larger than necessary on account of the enlarged value of the factor $r$.

This analysis shows clearly that the factor $H_2$ can never be reduced to zero; it has a certain definite minimum value, which is given by the following equation:

$$H_{2\,0} = R\ T_0 \log. \frac{P_1}{P_0}$$

When the discharged heat has been reduced to the atmospheric temperature, it has reached the equalized or stable state and cannot further be utilized for the production of useful work. Consequently, the maximum amount of *available* work which can possibly be produced for a given amount of unstable heat $H_1$, by any cycle whatsoever, is,

$$W_{max} = H_1 - H_{2\,0} = R\,(T_1 - T_0) \log._e \frac{P_1}{P_0} \qquad (20)$$

where $T_1$ = absolute temperature of the source of heat.

$T_0$ = mean absolute temperature of the atmosphere.

$H_1 = R\ T_1 \log._e \frac{P_1}{P_0}$ = amount of unstable heat supplied during isothermal expansion.

$H_{2\,0} = R\ T_0 \log._e \frac{P_1}{P_0}$ = the minimum amount of heat which can be discharged into the refrigerator (*i. e.*, atmosphere) for given conditions of transformation.

The corresponding thermodynamic efficiency is,

$$E_{max} = \frac{W_{max}}{H_1} = \frac{T_1 - T_0}{T_1}. \qquad (21)$$

In this formula, the factor $(T_1 - T_0)$ is the temperature *head* which the working substance possessed initially with respect to the atmospheric temperature; hence, equation (21) may take the final form:

$$E_{max} = \frac{t_1}{T_1} \qquad (22)$$

where $E_{max}$ = the greatest fractional part of a given amount of unstable heat energy at a given absolute temperature $T_1$, which can possibly be converted into useful work.

$t_1 = T_1 - T_0$ = temperature head of the source of heat with respect to the atmospheric temperature.

The above equation, which may be considered as the mathematical statement of the second law of thermodynamics, is the relation required to eliminate one of the two independent variables of equation (1).

A complete definition of the second law of thermodynamics may be stated as follows:

Every heat-energy transformation must be impelled by a difference of thermal potential. Such difference of potential is proportional to the temperature head, which, in turn, measures the unstable heat energy residing in a unit weight of working fluid. Only the *unequalized* portion of heat energy can be converted into work, and of such work only a fractional part can be utilized as *available* motive power. The greatest possible efficiency with which unstable heat can be transformed into available work is equal to the ratio of the temperature head of the working substance to its corresponding absolute temperature.

If, instead of expanding down to atmospheric temperature, heat is discharged from the engine at an absolute temperature $T_2$, which is higher than $T_0$, the maximum efficiency of the cycle will be that of the Carnot, as shown by

equation (19). In terms of temperature heads, the efficiency formula can also be written in the following form:

$$E = \frac{t_1 - t_2}{T_1} \qquad (23)$$

where $t_1$ = temperature head, with respect to the mean atmospheric temperature, at which all heat has been supplied to the engine.

$t_2$ = temperature head with which all the heat has been discharged from the engine.

$t_1 - t_2$ = effective temperature head of the working substance.

$\frac{t_1 - t_2}{t_1}$ = measure of the relative waste of potential as compared with the efficiency $E_{max}$.

The thermal efficiency factor $E$ determines, relatively, the greatest amount of *effective* rectification of the unstable heat motion which can be produced for given conditions of transformation. It is immaterial by what means this process of rectification is accomplished.

Equation (23), which is really a combination of the first and second laws of thermodynamics, shows clearly that when no temperature *head* is available in the working substance, it is impossible to produce useful work. This modified form of the Carnot efficiency formula, which the writer proposes, is based upon the principle of unstable energy as the essential requirement for the production of useful work; in this respect it is essentially different from the derivation of the Carnot efficiency formula, which is deduced for total or absolute temperature heads, and hence does not discriminate between stable and unstable heat energy.

The Carnot formula leads one to infer, fallaciously, that even when heat is discharged from an engine at atmospheric temperature, such heat still contains available potential, while, as has been proved, the available unstable heat energy of the working substance has already been fully utilized. The proposed modification does not become identified with the efficiency formula for the perfect heat engine until the essential factor of thermal instability is introduced in terms of a temperature head. In the writer's opinion,

the insertion of this factor into the Carnot efficiency formula and a careful discrimination between equalized and unequalized heat will undoubtedly eliminate much of the ambiguity which is frequently encountered in interpreting fundamental thermodynamic principles.

In a thermodynamic cycle, every temperature change which is not the effect of change of volume or chemical action, is necessarily due to the direct passage of heat from a hot into a colder body, and represents a loss of available motive power. When this dissipated heat is allowed to pass into unisolated atmosphere, it invariably results in a complete loss of thermal potential. Such changes are irreversible, inasmuch as a certain portion of the initial amount of unstable heat permanently loses its relative temperature head. A cycle is not reversible unless the entire unstable energy in a unit weight of working fluid remains under complete control.

The availability of heat energy will, of course, be permanently decreased by every energy change unless the intensity head lost by one form or mode of energy is fully compensated by the appearance of an equivalent available intensity *head* of another form or mode of energy. Such an ideal transformation is possible only in a perfectly *isolated* system. All the previously discussed perfect transformations presuppose that it is practicable to isolate a system in such a manner as to absolutely prevent exchange of energy with external systems.

In practice it is practically impossible to isolate kinetic energy completely because the unequalized portion of energy is readily affected by certain irreversible processes, such as conduction, radiation, etc., which we cannot adequately control.

In regard to isolation, the transformation into work of a low thermal intensity possesses several important thermodynamic advantages, as can be proved by comparing the actual indicator card areas of the steam and gas engines with their respective ideal card areas. The ratio for the low intensity steam engine is considerably greater than that of the gas engine which works with a high intensity head.

This unfavorable comparison as regards the gas engine is due principally to the necessity of artificially cooling the cylinder walls.

Eventually the thermal loss resulting from the water jacket in the gas engine will, no doubt, be considerably reduced. This difficult problem could be partially solved by shielding the cold metallic walls during combustion, so as to prevent the instability of explosion from getting away. For practical reasons the isolating medium should not consist of a solid substance, but rather of an inert portion of the working substance itself; that is, a concentric or annular charge of pure air should be made to surround the explosive mixture during combustion. This suggestion is in accordance with the tenor of the above thermodynamic discussion of thermal instability, and if the idea could be fully applied in practice it would unquestionably result in a decided improvement in economy of internal combustion motors.

It is radically wrong to adopt very high temperature heads for heat-engine cycles without at the same time providing a correspondingly perfect system of isolation for the working substance. It is true that the initial temperature head should be made as high as possible in order to realize maximum thermal efficiency, because relatively it reduces the amount of heat discharged, but this principle should not be carried to the point where we almost completely lose control of the process of transformation. The present tendency to use excessively high temperature in the gas engine is in a large measure due to blindly following Carnot's law of thermal efficiency; according to this law the thermal efficiency can only reach a maximum when the temperature of the source $T_1$ reaches its greatest possible value. Such a distractive treatment of the real heat-engine problem often leads to entirely wrong conclusions. Instead, thermal efficiency for the real heat engine ought to be measured by means of the following modified formula, because it permits far more comprehensive conclusions to be drawn regarding the requirements of the real heat-engine cycle.

In analyzing the real heat-engine cycle it is necessary to

take into account the isolation factor. This very important factor has heretofore been entirely overlooked in theoretical discussions. Actually, the resultant efficiency of a heat-engine cycle may be thought of as consisting of two opposing theoretical factors, as shown by the following equation, which readily leads to a rational solution of the heat-engine problem:

$$E_i = E_t \quad . \quad E_c = \frac{t_1 - t_2}{T_1} \quad . \quad E_c \qquad (24)$$

where $E_i$ = theoretical indicated efficiency of the cycle.
$E_t$ = thermodynamic efficiency of the perfect heat engine.
$E_c$ = efficiency of isolation; this factor varies inversely with the initial temperature heat $t_1$.

In the final form, the heat-engine formula discloses the fact that the maximum resultant efficiency of a thermodynamic cycle can be obtained only when the product of the thermal efficiency $E_t$ into the efficiency of isolation $E_c$ reaches its greatest possible numerical value. Since these factors vary in opposite directions, there is a certain maximum attainable efficiency for every type of heat-engine cycle; this resultant efficiency $E_i$ does not become a maximum for maximum effective temperature head $(t_1 - t_2)$ unless the isolation of the working substance is perfect, *i. e.*, when $E_c = 1$.

The more nearly perfect the isolation, the more closely may the theoretically possible transformations be verified. The introduction of the isolation factor places the theoretical discussion of the heat-engine cycle for high temperature heads upon a sound basis, and so tends to diminish the discrepancies which still exist between the theoretical and practical heat-engine problem. In so far as no real system can be completely isolated, the essential factor of isolation ought not to be omitted from the efficiency formulæ for heat engines. The isolation or condensation factor is really the principal component of the so-called "experience or card factor" which must be applied to all deductions from theoretical indicator cards so as to make the theoretical cal-

culations for fuel consumption, etc., conform with those actually obtained in practice.

According to the above principle, all attempts to increase the thermal intensity factor of a gas-engine cycle at the expense of the isolation factor must necessarily result in a loss of indicated efficiency. Equation (24) shows clearly that the efficiency of the present types of internal combustion motors cannot be radically improved so long as the high thermal potential resulting from combustion is permitted to come in direct contact with the comparatively cold cylinder walls. A substantial reduction in the jacket loss of the existing gas engines can be secured only by suppressing this heat waste by means of the aforesaid method of thin annular charges of cool fresh air or its equivalent.

The successful application of the isolating charges of pure air depends upon devising simple means which would control the distorting effects of the intense conduction currents, so as to insure and maintain a comparatively thin but effective stratification during explosion; otherwise, the cylinder dimensions and friction of the engine would be increased without realizing a corresponding net gain in efficiency. The sudden expansion of the explosive charge during combustion increases the temperature of the surrounding layer of inert air to a certain extent by mechanical air, and so prevents an excessive rise of the combustion temperature. With increased isolation of the working substance the ratio of expansion of the engine would have to be increased considerably, in order that the decreased jacket loss would not be accompanied by an increased exhaust loss.

Besides the theoretical advantages of increased isolation, the concentric stratum of air adjacent to the cylinder wall has the additional practical advantage of facilitating the lubrication of the sliding parts. In fact, the proposed layer of isolating air largely overcomes many of the disadvantages of the water jacket without forfeiting its indispensable practical advantages. The foregoing suggestions regarding the improvement of the isolation factor indicate the lines along which further increase in the economy of the internal combustion motor is to be sought.

# Correspondence.

## THE INTERNATIONAL CONGRESS OF ARTS AND SCIENCES, SEPTEMBER 19–25, 1904.

The scope of this Congress was very broad, as it was the purpose of its originators to collate the best and most recent data in the entire field of human knowledge, by means of specialists well versed in their particular fields of research, and to submit a symposium of their papers to the Congress for presentation in permanent form.

Thus, while the industries, resources and products of all the nations of the earth were assembled in visible and material forms, revealing their physical properties, it was deemed necessary to supplement these by the psychological elements, which are, in fact, the basis of the wonderful inventions and products of this generation.

To this end a broad classification of subject-matter was carefully prepared by the Administrative Board, composed of Dr. Howard J. Rogers, Director of the Congress; Drs. Nicholas M. Butler, Wm. P. Harper, R. H. Jesse, Henry S. Pritchett, Herbert Putnam and F. J. V. Skiff.

It is not possible to summarize the ramifications of the various divisions of this scheme further than to state that the Normative Sciences, embracing:

| | Groups. |
|---|---|
| Philosophy and mathematics were subdivided into . . . . . | 9 |
| Historical sciences, political and economic history into . . . . . | 32 |
| Physical science, physics, chemistry, astronomy, the earth, biology and anthropology into . . . . . | 31 |
| Mental science, psychology and sociology into . . . . . | 6 |
| Utilitarian sciences, medicine, technology, economics into . . . | 24 |
| Social regulation, politics, jurisprudence, social science into . . | 14 |
| Social culture, education and religion into . . . . . | 11 |

Making 127 subdivisions, in each of which two distinguished specialists were selected to prepare and present in person (*a*) "The Fundamental Conceptions and Methods" of his theme; (*b*) "The Progress during the Last Century." These were followed by miscellaneous ten-minute papers and discussions.

It is needless to add that the representation gathered from all quarters of the globe constituted an imposing spectacle as they were assembled as the guests of the Management of the Exposition in the Swiss Pavilion, where President Francis entertained over 700 of them at dinner.

The program of the Congress was admirably executed by its officers, Prof. Simon Newcomb, President; Dr. Hugo Muensterberg, Vice-President; Prof. Albion W. Small, Honorary Vice-President; Right Hon. Jas. Bryce, M.P., M. Gaston Darboux, Wilhelm Waldeyer, Oskar Backlund, Theodore Escherick, Attilio Brunialti.

The Executive Secretary was Dr. L. O. Howard, the Permanent Secretary of the American Association for the Advancement of Science. No reference can be made to the personnel of this Congress, or the subject-matter of the

papers, without seeming to make invidious distinctions. The papers and discussions, it is expected, will be published at the close of the Exposition as a part of its proceedings.

LEWIS M. HAUPT.

PHILADELPHIA, October 7, 1904.

### THE INTERNATIONAL ENGINEERING CONGRESS, LOUISIANA PURCHASE EXPOSITION.

Following in the wake of the Congress of Arts and Sciences came that of the Engineering Profession. This was likewise a representative gathering of men of great executive and administrative ability from all corners of the earth.

The papers and subjects presented for discussion were classified under the general topics of: (*a*) Harbors; Waterways, Natural and Artificial; Traffic, Dredges, Wharves and Piers, presided over by Alfred Noble. (*b*) Water Supply, Sewage Disposal, Municipal Refuse, under J. J. R. Croes. (*c*) Railroad Terminals, Underground Railroads, Live Load for Bridges, Ventilation of Tunnels, under Robert Moore Stearns. (*d*) Manufacture of Steel and Cement, Concrete, Tests of Materials, under F. P. Stearns. (*e*) Water for Steam, Turbines, Rolling Stock, Elevators, Pumps, under Wm. Metcalf. (*f*) Electricity, under Frank J. Sprague. (*g*) Military, Naval and Marine, Lighthouses, Docks, under Wm. P. Craighill. (*h*) Miscellaneous, Irrigation, Highways, Deep Foundations, Mining, Education, Surveying, under Octave Chanute.

The sessions of the Congress extended from Monday, October 3d, to the 8th, and up to its close there were over 850 registrations. The countries represented include the most progressive nations of the earth, and the problems submitted for discussion covered those relating to the more rapid development of international commerce; the increasing demands for cheaper and more abundant power; the necessity for greater sanitary precautions in large cities; the latest improvements in use of structural materials, especially in steel and concrete, and the demand for larger internal waterways for domestic commerce.

The foreign delegates were the guests of the American Society of Civil Engineers, over which Charles Hermany presides.

The papers will be published as a part of the proceedings of the American Society, and will form an invaluable addition to the record of the century.

PHILADELPHIA, October 7, 1904. LEWIS M. HAUPT.

## Notes and Comments.

### ASBESTOS PRODUCTION.

According to a report made to the Geological Survey by Dr. Joseph Hyde Pratt, the production of asbestos in the United States in 1903 was only 874 short tons, which compares with 1,005 short tons in 1902. Most of the asbestos reported in 1903 came from the mine at Sall Mountain in White County, Ga., but small quantities were mined at Dalton in Berkshire County, Mass., and near New Hartford in Connecticut. Some deposits near Lowell, Vt., are being explored.

## PYRRHOTITE AS A SOURCE OF SULPHUR.

According to Ernst A. Sjöstedt, in a paper read before the Canadian Mining Institute, March, 1904, the manufacture of sulphuric acid from pyrrhotite has been successfully accomplished at Sault Ste. Marie. The ore (from Sudbury) contains 15 to 20 per cent. sulphur, 1 to 3 per cent. nickel, and 0·5 to 2 per cent. copper. The ore is sorted into two classes; one high in copper and low in sulphur; the other low in copper and high in sulphur. The former is smelted to matte in the ordinary way; the latter is sent to the acid plant. It averages about 28 per cent. S, 3 per cent. Ni, 0·5 per cent. Cu and 50 per cent. Fe. The roasting is done in a modification of the Herreshoff furnace, the external cylindrical form being abandoned and four shafts constructed in a block, loss of heat by radiation being thus reduced. In this way, and with other means to conserve heat, designed in accordance with good engineering practice, satisfactory results have been obtained. The furnaces are constructed in muffle-form, arranged for gas-firing, but improvements in the details and increase in experience enabled that to be dispensed with, and ore as low as 20 to 25 per cent. S has been burned down to 1 to 3 per cent. S, producing a gas with 6 to 10 per cent. $SO_2$, without the use of any extraneous fuel. The plant comprises four blocks of kilns with an aggregate capacity of 40 tons of ore per day, and, up to the time of writing, had burned 10,000 tons of pyrrhotite and 3,000 tons of pyrites. The experience is very valuble, showing how a poor sulphur ore can be almost completely burned without extraneous fuel when proper means are taken to avoid loss of heat in excess air, by radiation and otherwise.—*Engineering and Mining Journal.*

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## RADIUM AND THE DIAMOND.

In the course of some experiments concerning the effect of the emanations from radium upon diamonds, Sir William Crookes made a curious discovery. When a diamond was placed in the path of the radiations it was converted from the carbon crystal into the common form of graphite, while in addition its color was quite changed. As a result of this strange metamorphosis Sir William Crookes suggests that the radium rays may prove of great commercial value to the jeweler, since by this means diamonds which are of an indifferent and defective color may be appreciably increased in their commercial value by treatment under the radium rays. He also observed that prolonged action of the radium also increased the intensity of the pale-colored gems.—*Scientific American.*

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## STATISTICS OF PETROLEUM.

It is not yet half a century since Col. Drake discovered petroleum on the waters of Oil Creek, near Titusville, Pa. The total production of crude petroleum from 1859 to 1902—forty-three years—has been no less than 1,165,280,727 barrels. Of this output, Pennsylvania and New York contributed 53·9 per cent.; Ohio, 24·3 per cent.; West Virginia, 11·3 per cent.; Indiana, 3·9 per cent.; California, 3·6 per cent.; Texas, 2·1 per cent.; leaving 11 per cent. to be supplied by Kansas, Colorado, Louisiana, Illinois, Missouri, Indian Territory, Wyoming, Michigan and Oklahoma.

## THE PRODUCTION OF FLINT AND FELDSPAR IN 1903.

The production of flint or quartz in 1903 amounted to 40,046 short tons of crude flint, valued at $38,736 and 15,187 short tons of ground flint, valued at $118,211, a total of 55,233 short tons, valued at $156,947. This was an increase of 18,868 short tons in production and of $12,738 in value. The quarries of Wisconsin and Virginia were idle in 1903, as were also several in other States. The States that furnished the production of 1803 were Connecticut, Maryland, New York, North Carolina and Pennsylvania.

These figures do not represent the entire amount of flint consumed annually in the United States, for much is imported from Europe in the form of rolled flints. The value of the flints and flint stone, unground, imported in 1903, was $101,103.

The production of feldspar in 1903 amounted to 13,432 short tons of crude eldspar, valued at $51,036, and 28,459 short tons of ground feldspar, valued at $205,697, a total of 41,891 short tons valued at $256,733. This is a decrease from the total production of 1901 of 3,396 short tons, but an increase in value of $6,311. The States that contributed to this production were Connecticut, Maine, Maryland, New York and Pennsylvania. These figures do not show the entire amount of spar consumed in this country annually, for some is imported from Canada.

The above data are taken from a report made to the United States Geological Survey by Dr. Heinrich Ries, on the production of flint and feldspar in 1903. The report is an extract from the forthcoming volume on "Mineral Resources of the United States in 1903," which may be obtained, free of charge, from the Director of the United States Geological Survey, Washington, D. C.

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## BORAX IN THE UNITED STATES.

The borax fields of the United States are mainly in the desert "dry lake" region of Southern California, though deposits are found also in Nevada and Oregon. Borax was first produced in the United States in 1864, at Borax Lake, California. The borax was contained in the water of the lake and was obtained by evaporatiou.

The saline crusts of the so-called dry lakes or borax marshes of the Mohave Valley were next mined for borax, and afterward, about in 1888, work was begun on the beds of colemanite, or borate of lime, in San Bernardino County, Cal., from which most of the borax mined in the United States has since been obtained.

The amount of crude borax produced in the United States in 1903 was 34,430 short tons, valued at $661,400. The production in 1902 was 17,404 short tons of refined borax, valued at $2,447,614, and 2,600 short tons of crude borax, valued at $91,000, a total of 20,004 short tons, valued at $2,538,614. Of the refined borax 862 short tons, valued at $150,000, were boric acid. Had the valuation in 1903 been taken on the refined instead of the crude product, the figures would have been $2,735,000 instead of $661,400.

The amount of borax, borates and boric acid imported into the United States in 1902 was 1,694,251 pounds, valued at $63,236. In 1903 the amount imported was 909,251 pounds, valued at $47,018.

Refineries for borax are located at Bayonne, N. J., Brooklyn, N. Y., New Brighton, Pa., Chicago, Ill., and San Francisco, Cal., where various more or less secret processes are employed to convert the crude material into products designed for various uses.

Borax is used for many purposes. When melted at a high temperature it dissolves metallic oxides and forms transparent colored glasses. It is used as a flux in welding metals and in melting gold and silver. It is employed in the manufacture of granite iron ware and of enameled bath tubs and other articles, as well as in making pottery and earthenware. Manufacturers of the hard, tough grades of glass and of encaustic tiles are large users of borax. It is used by painters, tanners, hat makers and calico makers, as well as by beef packers.

The domestic uses of borax are widely known, and in chemistry and metallurgy the borates are employed in many ways.

A clear account of the borax industry in the United States is given in a pamphlet entitled "The Production of Borax in 1903," by Charles G. Yale, forming a chapter in "Mineral Resources of the United States, 1903," from which the above facts have been taken. This pamphlet, which contains detailed statistics covering the production and importation of borax in 1902 and previous years, is printed for gratuitous distribution and may be had by application to the Director of the United States Geological Survey.

## QUICKSILVER MINES IN PERU.

In a recent bulletin issued by the *Cuerpo del Ingenieros de Minas del Peru*, Augusto F. Umlauff gives an interesting account of the ancient quicksilver mines of Huancavelica. The mines were discovered in 1566, and during their long career have made an estimated output of 1,116,235 quintals (55,800 metric tons) of quicksilver. The last period of successful operation was from 1846 to 1849, when the production averaged 20 quintals per week. The ore is cinnabar and occurs in veins and stockworks intersecting a series of sedimentary rocks, mostly limestone, sandstone and quartzite, and as disseminated masses along the contact of igneous intrusions. Altogether the deposits can be traced from Chunamachay on the northwest to San Antonio on the southeast, a distance of several kilometers, although not in a continuous line. Samples taken by the writer from the old workings indicate that the ore runs about 2 per cent quicksilver. Beside the ore-bodies still remaining in the mines there are several heaps of waste and spent ore, aggregating 150,000 tons, which average 0·1 per cent. metal. The mines are situated 458 kilometers by wagon road from the port of Callao at an elevation of 14,000 feet above sea-level.—*Engineering and Mining Journal.*

## LIFE HISTORY OF RADIUM.

The view that uranium is the parent substance of radium was advanced by Rutherford and Soddy on the ground that it is one of the few elements having a higher atomic weight, that it is the main constituent of radium ores, and that the proportion of radium in good pitchblende corresponds roughly with the ratio of activity of radium and uranium. An examination of a number of specimens of uranium salts purchased from seventeen to twenty-five

years ago showed that these all contained a larger proportion of radium than the more modern specimens. This result is in accordance with the theory enunciated by Rutherford and Soddy, but may easily be due to modified methods of preparation. F. Soddy (*Nature*, 70, p. 30, May 12, 1904), states that a kilogram of uranium nitrate was purified until the proportion of radium present was less than $10^{-10}$ gram as tested by the maximum amount of accumulated emanation. At the end of twelve months the amount of accumulated radium was certainly less than $10^{-11}$ gram instead of the $5 \times 10^{-7}$ gram calculated from the ratio of the radio-activities of radium and uranium. The quantity of radium produced was therefore less than one ten-thousandth part of the theoretical quantity, and this result practically settles, in a negative sense, the question of the production of radium directly from uranium. It is, of course, possible that intermediate substances might exist, and that radium would only be produced at a later stage, but there is no experimental evidence in support of this view.

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## HENDERSON PROCESS OF COPPER EXTRACTION.

At wet copper works in Great Britain more difficulty is experienced than in alkali works generally, in keeping the chlorhydric acid gas evolved within due limits, partly because it has not proved convenient to construct the furnaces on the plus-pressure principle, as is usually the case. Dr. Affleck has reported ("Fortieth Alkali Works Report") that by burning a certain proportion of pyrites fines in a special furnace apart, at certain intervals, and mingling the gases with those from the other furnaces, in which the mixture of burnt copper ore with salt is calcined, all excess of chlorine in the gases is reduced, obviating the difficulty of absorption which otherwise arises.

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## THE RELATIVE EFFICIENCY OF THE STEAM TURBINE AND THE RECIPROCATING ENGINE.

The question of the relative efficiency of the steam turbine and the reciprocating engine is widely debated, and yet unsettled. In general the turbine seems to have the better of the argument for large units for steady duty, where superheated steam is used and a low vacuum maintained for the exhaust. The question of the efficiency of the high duty turbine or centrifugal pump is more debatable, though such pumps are in successful service at mines in continental Europe, and several concerns are manufacturing them in this country and giving out statements as to the work the pumps will do. It would seem from the present status of the arguments that the chief factor that manufacturers will have to overcome in centrifugal pumps for high lifts will be that of deterioration from use, particularly where mine waters are acid or gritty. A worn valve in a direct-acting pump, of good construction, can be replaced cheaply. Any wear of propeller blades, however, is likely to lead to considerable slip losses when working against high heads, and replacements seem likely to be costly. However, the theoretical advantages of the centrifugal pump, its compactness and possible high efficiency, will undoubtedly lead to its being given extended tests under conditions that will bring out any defects.—*Engineering and Mining Journal.*

# Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 19, 1904.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 19, 1904.

MR. H. R. HEVL in the chair.

Present, 60 members and visitors.

Additions to membership since last report, 8.

The chairman introduced Mr. J. Wilmer Henszey, of the Baldwin Locomotive Works, who delivered an interesting address "On the Organization and Methods of a Great Modern Industrial Works," using the Baldwin establishment as a typical example. Mr. Henszey's remarks were illustrated by the exhibition of a large number of lantern photographs of the various departments and shops. The paper will appear in the JOURNAL.

Mr. W. N. Jennings exhibited and commented on a large series of lantern photographs representing views taken in the course of a recent trip through the Yellowstone Park and the Canadian Rockies.

The communications of the evening were well received, and the chairman expressed the thanks of the meeting to the contributors.

Adjourned.

WM. H. WAHL,
*Secretary.*

## Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Wednesday, October 5, 1904.*)

MR. LOUIS E. LEVY in the chair.

The following reports were adopted:

(No. 2301.) *Hydraulically-forged Steel Car Wheel.* H. V. Loss, Philadelphia.

ABSTRACT: The report gives a historical sketch of the development of the inventions of Mr. Loss for producing a finished wheel of steel. For details of the machinery and methods designed by the inventor, the reader is invited to refer to the JOURNAL for May, 1904.

It appears that several mills have been built in Germany for rolling the centers of the wheels, the tires being produced in the ordinary tire mill and attached by various methods to these rolled centers. The Loss improvements, which had as their starting point the German practice, advanced the art to the rolling of the flange as well as the wheel center. The report then proceeds to describe the hydraulic press which the applicant devised for this purpose (U. S. Patent, No. 710,286, September 30, 1902), and which constitutes an excellent piece of mechanical design, and embraces several novel and original features; as, for example, the operation of the independent hydraulic ram, respectively for forging and punching, and which can be used in conjunction for exerting intense moulding pressure on the work.

The report further commends the ingenious method of releasing and withdrawing the punch; the method of discharging the punchings, and

also of taking the compressed blank out of the die. These features are referred to as examples of good mechanical design.

Referring to the illustrations accompanying Mr. Loss's papers (J.F.I., May, 1904), showing the machine in the Schoen works, near Pittsburg, the report states that while this is similar in general design to the original German mill, Mr. Loss has added some features which permit of the rolling of the flange of the wheel, making a much more powerful mill and applying much greater motive power than originally contemplated.

An adjustable external roll was applied for this purpose, together with companion rolls for finishing the flange, and side rolls for finishing the edge of flange, for detailed description of which reference is made to U. S. Patent, No. 706,674. August 12, 1902.

This machine has been in use in the Pittsburg works for the past year, and a considerable number of wheels have been successfully made and placed in service.

The report concludes as follows :

"The value of the process from a commercial point of view can only be told by experience, but the successful working of the machine and the convenience with which it can be operated bear testimony to the mechanical skill displayed by Mr. Loss in the execution of the designs. As there are doubts about any substantial originality in the design of the rolling mill, the Committee prefers to give precedence to the subject of the hydraulic press ; and, in consideration of its many novel features so well adapted for the intended purpose and the mechanical skill displayed, it is believed that he has accomplished a desirable advancement in the method of producing solid, rolled steel, car wheels. . . . The wheel blanks, instead of being cast to form, are now cast from slabs, rolled from the ordinary ingot, a method which should insure greater solidity and homogeneity than if cast to shape."

In view of the foregoing facts, the award of the John Scott Legacy Premium and Medal is recommended to Mr. H. V. Loss, for his improvement in the production of solid rolled steel car wheels. (*Sub-Committee*, James Christie, chairman ; Chas. Day, Robert Job.)

(No. 2332.) *Ratchet Tools.* North Bros., Philadelphia.

ABSTRACT: The object of this invention is to provide a compact, simple, powerful, reversible, and at the same time cheaply-made, ratchet.

This has been accomplished by abandoning entirely the conventional pawl carried by a pivot and vibrating in the plane of the toothed wheel, and substituting a thrust-block, which bears against the tooth of the wheel on one side and the casing on the other, thus giving a maximum of strength and simplicity in a minimum of space. The strength, instead of being limited by that of the pivot of a pawl, as in the usual case, is only limited by the size of the tooth in the wheel. The thrust-block is subjected only to compression, and can be made stronger than the tooth and at the same time be kept small in size and space occupied.

The simple and effective methods by which these thrust-blocks are made to transmit motion from the casing to the toothed wheel in either or both directions are fully described and illustrated by U. S. letters-patent Nos. 537,681, April 15, 1895, and 593,157, November 2, 1897, to which reference is made.

A very strong and efficient chuck is also provided at the end of the spindles of the tools for holding the bits.

The ingenious and effective manner in which this ratchet and chuck have been applied to hand tools for operating screw drivers and drills can best be appreciated by an examination and trial.

On account of the compactness, simplicity, strength and convenience of the tools, combined with the superior workmanship and economical production, due to efficient method and system of manufacture, the award of the John Scott Legacy Premium and Medal is recommended to be given to Zachary T. Furbish for his ratchet tools. (*Sub-Committee*, Wm. H. Thorne, chairman; D. Eppelsheimer, Jr., Arthur Falkenau.)

(No. 2334.) *Counterbore.* Robert E. Duvall, Philadelphia.

An advisory report.

The following reports passed first reading:

(No. 2284.) *Wire-testing Machine.* Falkenau & Sinclair, Philadelphia.

(No. 2340.) *Flanging and Expanding Machinery.* Luther D. Lovekin, Camden, N. J.

## Sections.

[*Abstracts of stated meetings.*]

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Thursday, October 6th, 8 P.M. Dr. Wahl in the chair. Present, 72 members and visitors.

Prof. A. E. Outerbridge made the inaugural address of the season on the subject of "The Molecule, the Atom and the Present Theory of Matter." The paper was discussed freely by Dr. E. Goldsmith, Mr. Waldemar Lee, the chairman and the author. It has been requested for publication.

The chairman *pro tem.* extended the thanks of the Section to Professor Outerbridge, and adjourned the meeting.

WM. H. WAHL,
*Secretary pro tem.*

CHEMICAL SECTION.—*Stated Meeting*, held Thursday, October 13th, 8 P.M. Dr. W. J. Williams in the chair. Present, 27 members and visitors.

The chairman introduced Mr. Waldemar Lee, who addressed the Section on "The Contact Process for Sulphuric Acid." Discussed by Dr. E. Goldsmith, Geo. P. Scholl and the author.

Dr. Bruno Terns followed with a paper on some problems in industrial chemistry. Following are the principal subjects discussed by the speaker, viz.:

"The Progress of the Coke-Oven By-Product Industry in the United States since 1891."

"The Manufacture of High-Grade Ammoniated Phosphates by the Direct Use of the Crude Ammoniacal Liquors of the Coke-Oven Industry."

"The Coke-Oven Process Applied to the Utilization of Garbage."

"Other Sources of Ammonia for the Fertilizer Industry."

Both papers are reserved for publication.

Adjourned.

WM. H. WAHL,
*Secretary pro tem.*

V. 19

## Improved Machinery, Apparatus and Processes.

[This department will contain from month to month descriptions of new machines, apparatus and processes. The data, for which the editor must depend largely on information derived from interested sources, will be carefully edited. The Committee disclaims responsibility.—THE COMMITTEE ON PUBLICATIONS.]

### REED'S SPEED JACK.

Following the discussion of the subject of "Electric Motor Drives for Machine Tools," published elsewhere in this impression, Mr. C. J. Reed described and exhibited in operation a speed controller of his

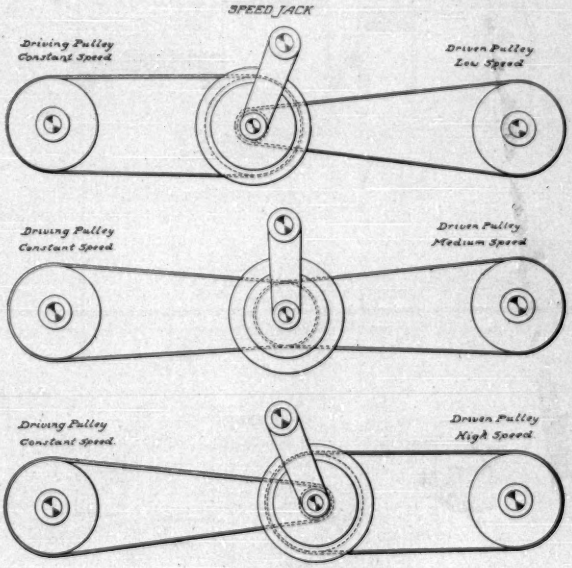


FIG. 1.

invention. The construction and action of the apparatus will be understood from the following description:

This mechanism consists of two expansible drums or pulleys operating in conjunction, the one adapted to expand, while the other simultaneously contracts in such a manner as to keep a practically uniform tension on the belt or chain.

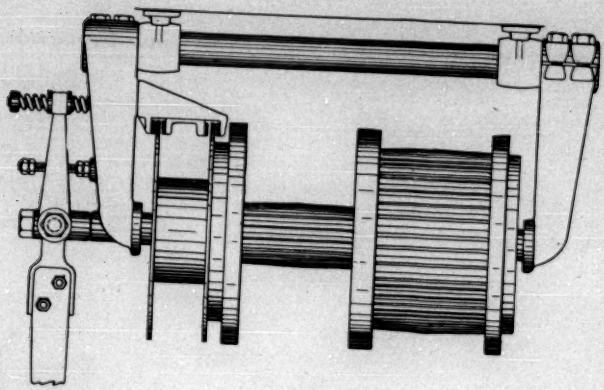

FIG. 2.

*Triple Drum*

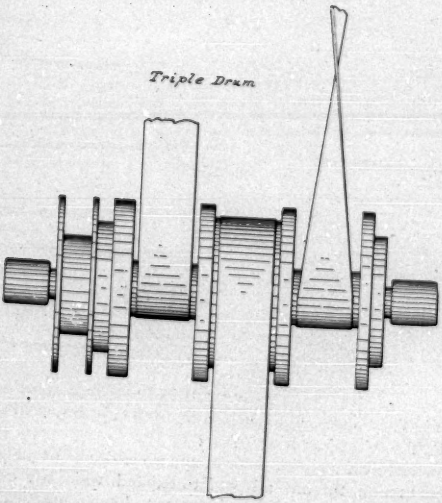

FIG. 4

The apparatus is built of two different forms or types. In one type the two drums carrying a single belt are on different shafts—one on the driving and the other on the driven shaft. In the second type, called

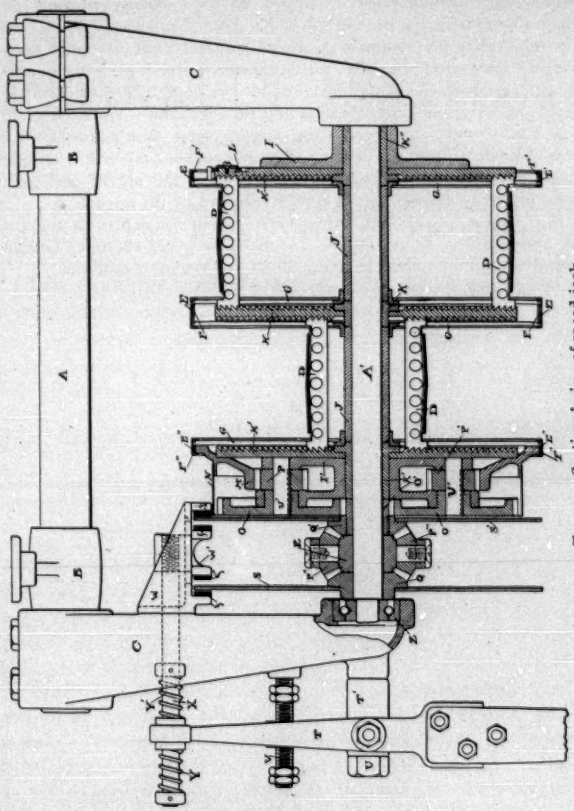

FIG. 3.—Sectional view of speed jack.

the "speed jack," both expansible drums (in some cases more than two drums) are on the same shaft, which is mounted so as to reciprocate between the driving and driven shafts, automatically taking a position which keeps the belt tension uniform. In this form each of the expansi-

ble drums is separately belted to a non-expansible pulley—one on the driving and one on the driven shaft.

*Fig. 1* shows the speed jack in three positions—those of minimum, medium and maximum speed. *Fig. 2* shows a connected view, and *Fig. 3* a longitudinal section of the jack. Each drum consists of a circle of parallel slats or rim-sections, whose toothed ends are held in the grooves of two scroll-threaded discs, mounted and keyed to the shaft. The rim sections are equally spaced in all positions by means of radially slotted guide plates movably mounted on the shaft. Rotation of the guide plates, with reference to the scrolls, causes the rim-sections to move towards or from the center. Suitable mechanical means are provided for producing this relative movement of the scrolls and guide plates, either by hand-power or power supplied by the apparatus.

*Fig. 4* shows a jack with three drums, two of which operate together and in opposition to the middle drum. This gives one open and one crossed belt on the driven shaft for direct and reversed motion.